UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 153

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Taxonomy of the Genus Phytophthora de Bary

COLUMBIA, MISSOURI
JUNE, 1931

#150 J. M. Anderson.

L. L. Harter

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ABSTRACT

Studies on the morphology of the sexual and asexual organs of one hundred fifty isolations representing most of the species of phytophthora indicate that morphological characters are of limited value in identifying species. The amphigynous or paragynous character of the antheridia is considered a constant character. Inoculations of various hosts reveal wide differences in pathogenicity between different isolations within some species while other species may be identified by their ability to attack certain plants. The growth of the isolations on corn meal agar at various temperatures indicates that the temperature relations of the species vary widely, are fairly constant within species, and that the character is a valuable aid in distinguishing certain species.

The ability of isolations to survive winter temperatures and long periods in culture is not generally correlated with the production of certain types of reproductive organs, but is, apparently, an inherent character of the particular species or strain.

The taxonomic position of the genus and species is considered in detail and a key for the identification of species is included. The characters considered of most importance for taxonomic purposes are ability to grow on certain media, type of antheridium, character of sporangium, temperature relations and, in a few species, development of certain types of reproductive organs, size of oospores and pathogenicity. The following species are maintained as valid and identifiable by these criteria: *P. infestans*, *P. cactorum*, *P. phaseoli*, *P. colocasiae*, *P. citrophthora*, *P. thalictri*, *P. palmivora*, *P. syringae*, *P. parasitica*, *P. erythroseptica*, *P. cambivora*, *P. cryptogea*, *P. capsici*, *P. cinnamomi*, *P. richardiae*, and *P. boehmeriae*. A new variety, *P. parasitica* var. *nicotianae*, and a new species, *P. drechsleri*, are described.

Taxonomy of the Genus Phytophthora de Bary*

C. M. Tucker

The investigations reported in the following pages are an outgrowth of work on coconut bud rot, caused by *Phytophthora palmivora* Butler in Porto Rico, which was published in 1925 (226). A number of Phytophthoras were received from various sources for comparison with those being studied, and these were retained as the nucleus of the larger collection which now contains about one hundred fifty cultures representing nearly all the described species. The geographical distribution of the cultures extends to five continents, but North America and Asia have been the sources of a large majority.

The major portion of the investigations has been done at the Porto Rico Agricultural Experiment Station at Mayaguez, P. R. During the academic years 1926-27 and 1929-30 researches were conducted in the laboratories of the botany department of the University of Missouri at Columbia. In September, October and November, 1929, the writer used the controlled temperature equipment of the Boyce Thompson Institute at Yonkers, N. Y. for a study of the temperature relations of the isolations. Investigations carried out at Columbia, Mo., and Yonkers, N. Y. will be designated, while those in connection with which no locality is cited were done in Porto Rico.

From the beginning the writer was impressed by the difficulties in classifying species of Phytophthora. Cultures received from various regions under different names were sometimes indistinguishable while other cultures received as isolations of the same species showed marked differences. Throughout the work this need of a method for identification has been borne in mind. The needed taxonomic scheme should be simple and not require the use of chemicals, culture media, or equipment not readily available in any fairly well equipped pathological or mycological laboratory.

Physiological specialization has been studied extensively in certain groups of fungi, e. g. the Uredinales. One of the purposes of this investigation has been to determine if, and to what extent, such specialization occurs within species among the Phytophthoras.

*Portion of a thesis submitted to the faculty of the Graduate School of the University of Missouri in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The geographical distribution of some species seems to be identical with host distribution, while other species appear, in nature, to be limited to particular areas where temperature and moisture conditions become coincidentally such that the species is able to reproduce with extreme rapidity, and cause extensive infection and consequent crop losses. Correlations between geographical distribution and temperature relations will be pointed out.

Species vary considerably in the types of reproductive bodies borne in cultures, and a portion of this investigation has been an attempt to correlate the ability of species to survive, in culture, the alternate freezing and thawing during Missouri winters, and to survive the long dry seasons of the tropics with the types of spores present in the cultures. The species are suitable for this type of investigation as they vary from strictly mycelial cultures to those producing sporangia, chlamydospores and oospores in abundance.

The cooperation of pathologists and mycologists, who will be mentioned in connection with the isolations has made the collection of cultures possible. To each of these, the writer is grateful. Much of the bibliographical work was done in the library of the Department of Agriculture at Washington, an arrangement made possible by the kindly interest of D. W. May, Director of the Porto Rico station, and W. H. Evans, Chief of the Division of Insular Stations. The writer is indebted to William Crocker, director of the Boyce Thompson Institute, for the use of its excellent equipment. Some phases of the researches were carried out at the University of Missouri, and valuable suggestions and advice were generously given by W. J. Robbins and W. E. Maneval.

A brief general statement regarding the morphology of the genus, Phytophthora, may be helpful. The hyphae are branching, nonseptate at first, but becoming septate with age, variable in diameter, and sometimes swollen, nodose, or tuberculate. Asexual reproduction by the development of sporangia and chlamydospores is common in most species. Sporangia are produced on sporangiophores which differ slightly or not at all from vegetative hyphae. They are produced sympodially by the continued growth of the sporangiophores. The newly formed sporangium is pushed to one side and the sporangiophore resumes growth in the same general direction. In some species the sporangiophore resumes growth through the base of the evacuated sporangium; the new sporangium may be formed within the walls of the empty one or the sporangiophore may grow out through the opening through which the zoospores emerged and produce the next sporangium some distance beyond the last. The sporangia are subspherical, oval, limoniform or pyriform; variable in shape and size; hyaline to light yellow; a definite,

hyaline apical papilla is usually present (Fig. 1), but some species produce non-papillate sporangia (Fig. 2). In exceptional cases two or more papillae may be present. The sporangia germinate directly by the emergence of one to several germ tubes, usually near the papilla, or indirectly by the division of the contents into a variable number of zoospores, which are fully developed within the sporangium. They are liberated by the dissolution or breaking away of the papilla, and emerge in amoeboid fashion through an opening smaller in diameter than the zoospores. They are kidney-shaped, with two cilia attached near the middle of the concave or flattened side. After swimming about for periods varying from a few minutes to several hours they lose the cilia, become rounded and develop a definite wall. Their germination is by a germ tube, or occasionally according to Drechsler (62) by the delivery of the protoplast through an evacuation tube as a secondary zoospore or by the production on a pedicel of a papillate, one-spored germ sporangium.

Fig. 1.—*P. palmivora* (No. I). Sporangia and chlamydospores from a steamed corn meal agar culture 2 weeks old. (x700).

Chlamydospores are spherical to ovoid or slightly irregular, non-papillate; hyaline to deep brown, usually lemon to straw-colored, thin to thick walled; they are produced acrogenously on short lateral hyphae or intercalarily. (Fig. 1). Germ tube germination occurs.

Fig. 2.—*P. drechsleri* n. sp. (No. 206). Sporangia borne on mycelium transferred to M/100 potassium nitrate solution. (x600).

Sexual reproduction by oogonia, antheridia and oospores is usual in some species while in others it occurs rarely or is lacking. Oogonia are spherical to pyriform, smooth, hyaline to yellowish, and enclose an oosphere, which, after fertilization, develops into a single smooth, spherical, hyaline to yellowish oospore occupying most of the interior of the oogonium. Definite observations on germinating oospores are few but they indicate that direct germination occurs. The antheridia are usually produced as the terminal cell of lateral branches. The paragynous type is attached to the oogonium wall, usually near or in contact with the oogonial stalk, but there is no evidence that the oogonial incept has penetrated the antheridium (Figs. 4 and 5). Paragynous antheridia sometimes have fallen away from numerous oogonia in old cultures. The amphigynous type of antheridium tightly clasps the stalk of the oogonium by which it has been penetrated, and remains attached permanently (Figs. 6, 7 and 8).

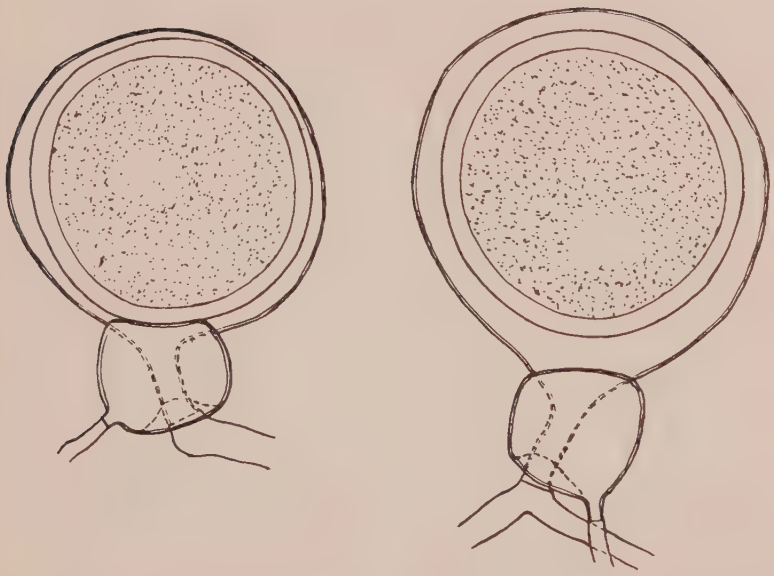

Fig. 3.—*P. drechsleri* n. sp. (No. 206). Oogonia, oospores and antheridia from an oatmeal agar culture 4 months old. (x1400).

Fig. 4.—*P. cactorum* (No. 196). Oogonia, oospores and antheridia from an oatmeal agar culture 2 months old. (x1600).

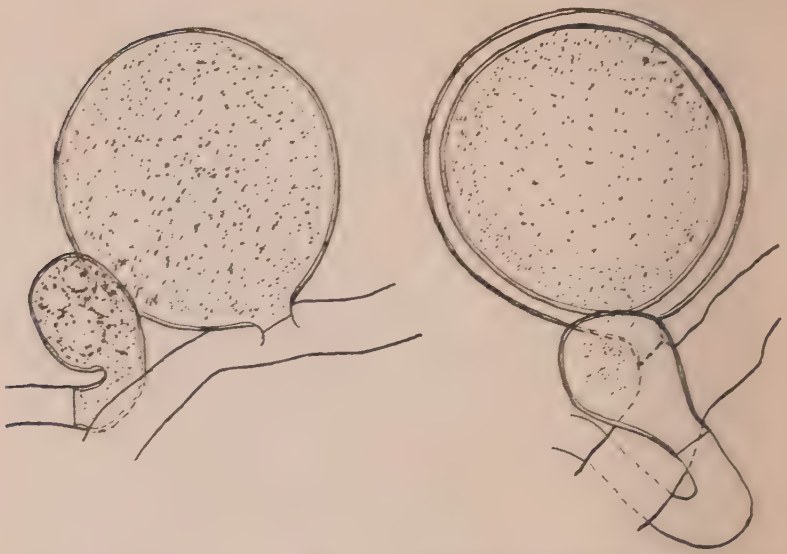

Fig. 5.—*P. cactorum* (No. 192). Left, oogonium and antheridium; right, oogonium, oospore and antheridium; all from a steamed corn meal culture 2 weeks old. (x1500).

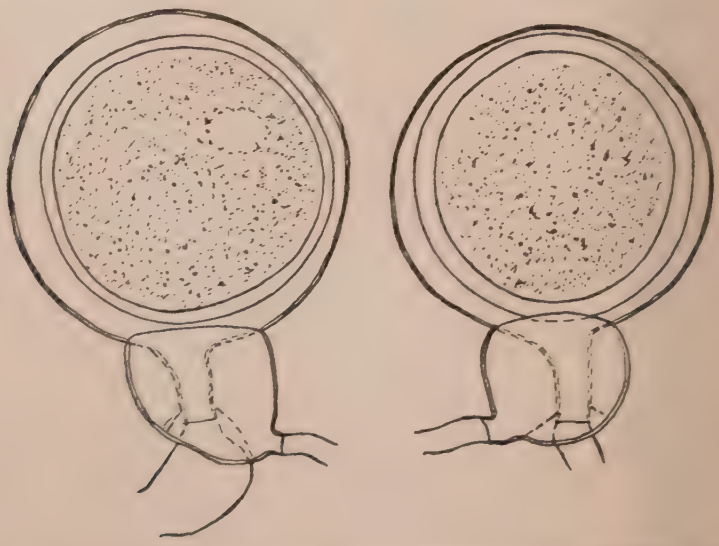

Fig. 6.—*P. mexicana* (No. 148) Oogonia, oospores and antheridia from an oatmeal agar culture 4 months old. (x1500).

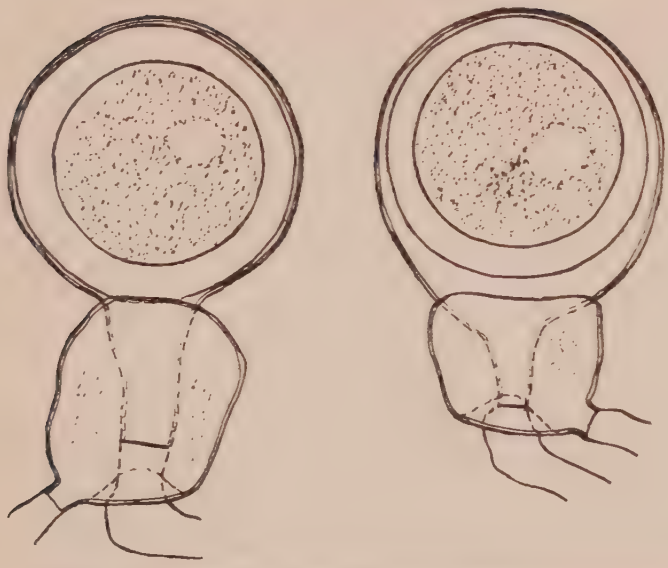

Fig. 7.—*P. cryptogea* (No. 150). Oogonia, oospores and antheridia from an oatmeal agar culture 3 months old. (x1700).

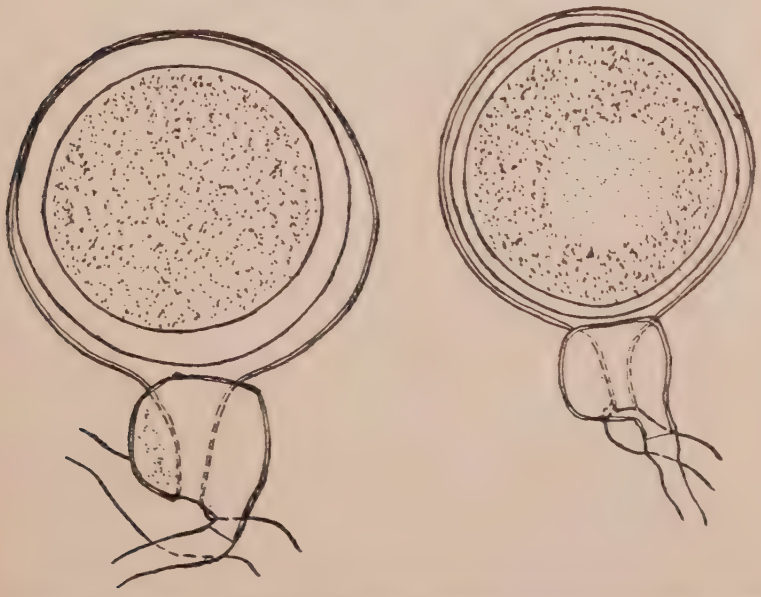

Fig. 8.—*P. parasitica* (No. 10). Oogonia, oospores and antheridia from an oatmeal agar culture 2 months old. (x1600).

Some reports of the occurrence of both types of antheridia in a single species have appeared. The writer has found that one type always predominates and that species with predominatingly paragynous antheridia are very easily distinguished from those in which the amphigynous type predominates.

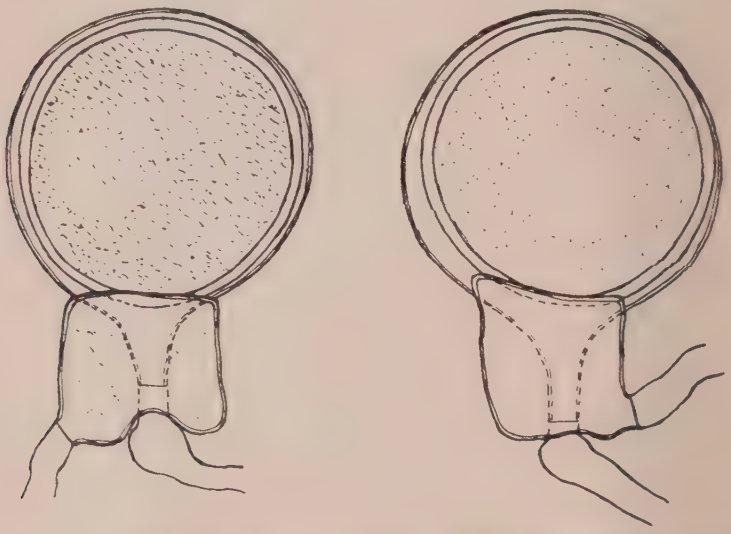

Fig. 9.—*P. parasitica* (No. 175). Oogonia, oospores and antheridia from an oatmeal agar culture 4 months old. (x1500).

II. Investigations

SPECIES AND STRAINS USED

Most of the cultures used have been supplied by the various investigators whose names are listed in Table 1, which contains information regarding the sources, etc. of the isolations, received with them. Information obtained subsequently from the published articles of other writers who have worked with some of the isolations will be cited in connection with a discussion of their identification.

TABLE 1.—ISOLATIONS USED IN THE INVESTIGATIONS

No.	Host	Isolated	Received from	Identification data received with cultures	Listed in subsequent tables as:
1	Cocos nucifera	Porto Rico Tucker—1924			P. palmivora (typ.)
2	Cocos nucifera	Philippines Reinking—1918	Ocfemia	P. faberi—bud rot	P. parasitica
3	Cocos nucifera	Jamaica Ashby—1920	Ashby	P. palmivora—bud rot	P. palmivora (typ.)
4	Theobroma cacao	Trinidad Ashby—1924	Ashby	P. faberi—pod rot	P. palmivora (typ.)
5	Theobroma cacao	Trinidad Ashby	Ashby	P. faberi—pod rot	P. palmivora (typ.)
6	Theobroma cacao	Philippines Roldan—1918	Ocfemia	P. faberi—pod rot	P. palmivora (atyp.)
7	Theobroma cacao	Ceylon Gadd	Gadd	P. faberi—pod rot	P. palmivora (typ.)
8	Gossypium barbadense	Porto Rico Tucker—1925			P. parasitica
9	Gossypium barbadense	St. Vincent Ashby	Ashby	boll rot	P. palmivora (typ.)
10	Gossypium barbadense	Montserrat Wakefield	Ashby	boll rot	P. parasitica
11	Gossypium barbadense	Trinidad Ashby	Ashby	boll rot	P. parasitica
12	Artocarpus incisa	Ceylon Gadd	Gadd	P. faberi	P. palmivora (typ.)
13	Carica papaya	Ceylon Gadd	Gadd	P. faberi—fruit rot	P. palmivora (typ.)
14	Hevea brasiliensis	Ceylon Gadd	Gadd	P. faberi—pod rot	P. palmivora (typ.)
15	Odontadenia speciosa	Ceylon Gadd	Gadd	P. faberi	P. palmivora (atyp.)
16	Dendrobium Maccarthiae	Ceylon Gadd	Gadd	P. faberi	P. palmivora (typ.)
17	Cocos nucifera	Florida Weber	Weber	P. faberi—bud rot	P. palmivora (typ.)
18	Theobroma cacao	Java Hartley—1920	Hartley	pod rot	P. palmivora (atyp.)
22	Theobroma cacao	Java Hartley—1920	Hartley	pod rot	P. palmivora (atyp.)
26	Theobroma cacao	Java Hartley—1920	Hartley	pod rot	P. palmivora (atyp.)
36	Theobroma cacao	Java Hartley—1920	Hartley	stem canker	P. palmivora (atyp.)
44	Theobroma cacao	Java Hartley—1920	Hartley	pod rot	P. palmivora (atyp.)
97	Erythrina sp.	Java Hartley—1920	Hartley	stem canker	P. palmivora (atyp.)
100	Theobroma cacao	Java Hartley—1920	Hartley	stem canker	P. palmivora (atyp.)

TABLE 1.—ISOLATIONS USED IN THE INVESTIGATIONS (CONTINUED)

No.	Host	Isolated	Received from	Identification data received with cultures	Listed in subsequent tables as:
102	Hevea brasiliensis	Java Vischer—1920	Hartley	stripe canker	P. palmivora (atyp.)
116	Hevea brasiliensis	Java Arens—1920 or 1921	Hartley	pod rot	P. palmivora (atyp.)
121	Theobroma cacao	Java Hartley—1921	Hartley	stem canker	P. palmivora (atyp.)
123	Borassus flabellifer	India ------—1921	Hartley	P. palmivora—bud rot	P. palmivora (typ.)
126	Cocos nucifera	Philippines Reinking—1918	Hartley	P. faberi—bud rot	P. palmivora (atyp.)
127	Carica papaya	Philippines Welles—1921	Hartley	P. faberi—fruit rot	P. palmivora (typ.)
130	Theobroma cacao	Java Hartley—1922	Hartley	stem canker	P. palmivora (atyp.)
132	Lycopersicon Lycopersicon	Porto Rico Matz—1921	Hartley		P. parasitica
136	Cocos nucifera	Philippines Reinking—1918	Hartley	P. faberi—bud rot	P. palmivora (atyp.)
137	Carica papaya	Philippines Welles or Reinking—1921 or earlier	Hartley	P. faberi—fruit rot	P. palmivora (typ.)
138	Solanum melongena	Philippines Reinking—1920	Hartley		P. palmivora (atyp.)
139	Solanum melongena	Philippines Reinking—1920	Hartley		P. parasitica
140	Hevea brasiliensis	Philippines Reinking—1920	Hartley	seedling bark infection	P. palmivora (atyp.)
141	Theobroma cacao	Philippines Reinking—1920	Hartley		P. palmivora (atyp.)
142	Hibiscus sabdariffa	Philippines Reinking—1920	Hartley		P. parasitica
143	Musa textilis	Philippines Reinking—1920	Hartley		P. parasitica
144	Citrus sp.	Philippines Reinking—1920	Hartley		P. parasitica
145	Theobroma cacao	Surinam Stahel—1921	Baarn to Hartley	P. faberi	P. parasitica
146	Sabal causiarum	Porto Rico Tucker—1926			P. palmivora (typ.)
147	Capsicum annuum	New Mexico Leonian	Leonian	P. capsici	P. capsici
148	Lycopersicon Lycopersicon	-------- - Hotson	Leonian	P. mexicana	P. mexicana
149	Pinus sp.	Minnesota Pierce	Leonian	P. pini	P. cactorum
150	Lycopersicon Lycopersicon (?)		Cotner to Leonian	P. cryptogea	P. cryptogea
151		India Dastur	Pethybridge or Talbot to Leonian	P. parasitica	P. parasitica
152	Caladium Colocasia	India McRae	McRae to Leonian	P. colocasiae	P. colocasiae
153	Areca catechu	India	Gundu Rao to McRae to Leonian	P. arecae	P. arecae
154	Citrus sp.	California Fawcett	Fawcett	1306—P. citrophthora	P. citrophthora
156	Syringa vulgaris		Baarn	P. syringae	P. syringae
159	Rheum Rhaponticum		Drechsler	P. terrestria var. rhei	P. parasitica
160	Pinus sp.		Rathbun to Drechsler	P. 372—P. pini	P. cactorum

TABLE 1.—ISOLATIONS USED IN THE INVESTIGATIONS (CONTINUED)

No.	Host	Isolated	Received from	Identification data received with cultures	Listed in subsequent tables as
161	Solanum melongena		Kendrick to Drechsler		P. parasitica
162	Lycopersicon Lycopersicon	New York Reddick	Drechsler	Leonian's "mutant" of Reddick's isolation	P. parasitica
164			Beach to Drechsler	P. terrestris	P. parasitica
165	Lilium harrisii or L. longifilorum	Bermuda	Drechsler	stump rot	P. parasitica
166			Reddick to Drechsler		P. parasitica
167			Baarn to Drechsler	P. terrestris	P. parasitica
168	Rheum Rhaponticum		Beach to Drechsler	P. cactorum	P. cactorum
169	Rheum Rhaponticum		Drechsler		P. parasitica
171			Jagger to Drechsler	P. terrestris	P. parasitica
172			Gardner to Drechsler	P. cactorum	P. cactorum
173	Cinnamomum burmanni	Sumatra Rands	Drechsler	P. cinnamomi 30.1	P. cinnamomi
174	Cinnamomum burmanni	Sumatra Rands	Drechsler	P. cinnamomi 35.1	P. cinnamomi
175	Rheum Rhaponticum		Drechsler	Leonian's rhubarb "mutant" IV.	P. parasitica
176	Solanum tuberosum		Baarn to Drechsler	P. erythroseptica	P. erythroseptica
177	Lycopersicon Lycopersicon		Kendrick to Drechsler	fruit rot	P. parasitica
178	Citrus paradisi	Porto Rico Fulton	Drechsler	fruit rot—P. R. 1	P. parasitica
179	Pyrus malus		Beach to Drechsler	P. cactorum	P. cactorum
180	Citrus paradisi	Porto Rico Fulton	Drechsler	fruit rot—P. R. 2	P. palmivora (atyp.)
181	Lycopersicon Lycopersicon		Kendrick to Drechsler	fruit rot—3265	P. parasitica
182	Solanum melongena		Kendrick to Drechsler	3269	P. parasitica
183	Capsicum annuum		Kendrick to Drechsler	fruit rot—3259	P. parasitica
184	Pyrus malus		Kendrick to Drechsler	3262	P. cactorum
185	Ananas Ananas	Jamaica	Hansford to Drechsler		P. parasitica
186	Lycopersicon Lycopersicon		Kendrick to Drechsler	fruit rot—3207	P. parasitica
187	Lycopersicon Lycopersicon	Washington, D. C. Drechsler	Drechsler	P. parasitica var. lycopersici	P. parasitica
189	Pyrus malus		Leonian to Drechsler	P. cactorum	P. cactorum
190	Lilium pyrenaicum		Drechsler		P. cactorum
191	Lycopersicon Lycopersicon		Drechsler	root disease	P. parasitica
192	Fagus sp.		Baarn to Drechsler	P. fagi	P. cactorum
193	Pyrus malus		Leonian to Drechsler	P. cactorum	P. cactorum
194	Lilium candidum		Drechsler		P. cactorum
195	Cinnamomum burmanni	Sumatra Rands	Drechsler	P. cinnamomi 13.1	P. cinnamomi
196	Pyrus malus		Drechsler	P. cactorum	P. cactorum
197	Solanum tuberosum	Kentucky	Drechsler	tuber rot	P. parasitica
198	Castanea sativa	Italy Petri	Baarn to Drechsler	Blepharospora cambivora	P. cambivora
199			Church to Drechsler	Church 524	P. parasitica
200			Drechsler	P. cactorum F. R. J. 600	P. cactorum

TABLE 1.—ISOLATIONS USED IN THE INVESTIGATIONS (CONTINUED)

No.	Host	Isolated	Received from	Identification data received with cultures	Listed in subsequent tables as
201	Solanum melongena	Philippines	Ocfemia to Drechsler		P. parasitica
202	Solanum melongena (?)		Drechsler		P. parasitica
203	Solanum tuberosum	Oklahoma	Drechsler	tuber rot	P. parasitica
204	Rheum Rhaponticum		Church to Drechsler	Leonian's rhubarb "mutant" V.	P. parasitica
205			Drechsler	F. R. J. 601	P. parasitica
206	Solanum tuberosum	Idaho	Drechsler	tuber rot—Idaho 969	P. drechsleri
207	Solanum tuberosum		Welch to Drechsler	P. infestans "error"—Drechsler	P. parasitica
208	Castanea sativa	Italy Petri	Baarn to Drechsler	Blepharospora cambivora	P. cambivora
209	Capsicum annuum		Kendrick to Drechsler	fruit rot—3259	P. parasitica
210			Baarn to Drechsler	P. cactorum	P. cactorum
211	Lilium regale		Drechsler	P. cactorum	P. parasitica
212	Lilium regale		Drechsler	P. cactorum	P. parasitica
213	Solanum melongena	Philippines	Ocfemia	P. melongenae	P. parasitica
216	Nicotiana tabacum	Florida Tisdale	Tisdale	P. nicotianae	P. nicotianae
217	Nicotiana tabacum		Leonian	P. nicotianae	P. parasitica
221	Citrus limonia	California Fawcett	Fawcett	1309 A—P. citrophthora gummosis	P. citrophthora
222	Citrus sinensis	California Fawcett	Fawcett	1341—P. citrophthora—fruit rot	P. citrophthora
223	Hevea brasiliensis		Baarn	P. meadii	P. meadii
227	Zantedeschia aethiopica	Holland Buisman	Baarn	P. richardiae	P. richardiae
228	Bryophyllum pinnatum	Porto Rico Tucker—1927			P. parasitica
230	Syringa vulgaris		Pethybridge to Baarn	P. syringae	P. syringae
232	Nicotiana tabacum	Porto Rico Nolla—1926	Nolla	black shank	P. nicotianae
234	Ricinus communis	India	McRae	P. parasitica	P. parasitica
235	Piper betle	India	McRae		P. palmivora (typ.)
236	Borassus flabellifer	India	McRae	P. palmivora	P. palmivora (typ.)
238	Hevea brasiliensis	India	McRae	P. meadii	P. meadii
239	Caladium Colocasia	India	McRae	P. colocasiae	P. colocasiae
241	Capsicum annuum	Italy Curzi	Baarn	P. hydrophila	P. hydrophila
242	Persea Persea	Porto Rico Tucker—1927			P. cinnamomi
243	Paeonia sp.	Indiana Gardner	Cooper		P. cactorum
244	Persea Persea	Porto Rico Tucker—1928			P. cinnamomi
245	Solanum tuberosum	Holland de Bruyn	Baarn	P. infestans	P. infestans
246	Citrus sp.	Australia	Kew to Baarn	P. hibernalis	P. hibernalis
247	Nicotiana tabacum	Sumatra Jochems	Baarn	P. nicotianae	P. nicotianae
248	Solanum tuberosum	New York Reddick	Reddick	P. infestans	P. infestans
249	Citrus sinensis	Porto Rico Tucker—1928			P. palmivora (typ.)
250	Citrus sinensis	Porto Rico Tucker—1928			P. palmivora (typ.)

TABLE 1.—ISOLATIONS USED IN THE INVESTIGATIONS (CONTINUED)

No.	Host	Isolated	Received from	Identification data received with cultures	Listed in subsequent tables as
251	Lycopersicon Lycopersicon	Porto Rico Nolla—1928	Nolla	infected seedling stem	P. parasitica
252	Solanum melongena	Porto Rico Nolla—1928		fruit rot	P. parasitica
253	Capsicum annuum	Porto Rico Tucker—1928			P. capsici
254	Vanda sp.	Java Schwarz	Baarn	P. faberi	P. palmivora (atyp.)
255	Cattleya sp.	Java Schwarz	Baarn	P. faberi	P. palmivora (atyp.)
257	Vanilla Vanilla	Java Schwarz	Baarn	P. meadii	P. meadii
258	Grammatophyllum sp.	Java Schwarz	Baarn	P. parasitica	P. parasitica
259	Pollia sp.	Java Schwarz	Baarn	P. parasitica	P. parasitica
260	Catharanthus roseus	Java Schwarz	Baarn	P. parasitica	P. parasitica
261	Hibiscus sabdariffa	Java Schwarz	Baarn		P. parasitica
262	Hibiscus sabdariffa	Java van Overeem	Schwarz to Baarn		P. parasitica
263	Vigna sp.	Java Schwarz	Baarn	P. parasitica	P. parasitica
264	Manihot sp.	Java Schwarz	Baarn		P. parasitica
265	Citrus paradisi	Porto Rico Tucker—1928			P. palmivora (typ.)
266	Boehmeria nivea	Formosa Sawada	Leonian	P. boehmeriae	P. boehmeriae
267	Citrus sp.	Formosa Sawada	Leonian	P. citricola	P. citricola
268	Bryophyllum pinnatum	Bermuda Ogilvie—1927	Chupp		P. parasitica
269	Catharanthus roseus	Bermuda Ogilvie—1926	Chupp	stem blight	P. parasitica
270	Lilium harrisii or L. longiflorum	Bermuda Ogilvie—1924	Chupp		P. parasitica
271	Antirrhinum majus	Porto Rico Tucker—1929			P. palmivora (typ.)
272	Mimusops elengi	Gold Coast Dade	Ashby	P. palmivora—fruit rot	P. palmivora (typ.)
274	Phaseolus lunatus	West Virginia Leonian—1929	Leonian	P. phaseoli	P. phaseoli

Cultures Nos. 254 to 260, and 263, isolated in Java by Miss Schwarz, were identified by S. F. Ashby at Kew, according to letters from Dr. Westerdijk of the Central Bureau voor Schimmelcultures at Baarn, who sent all cultures listed as received from Baarn. Nos. 254 and 255 are said to belong to the "cacao group" of *P. palmivora* (*P. faberi*). No. 257 was identified as *P. meadii*, largely from mycelial characters as it was practically sterile in culture.

Nos. 18 to 145 were sent by Hartley, accompanied by notes on some of the isolations. His numbers were retained except in one instance, when his No. 8 was changed to No. 18. He found Nos. 36, 44, 121 and 130 very similar in morphology and parasitism, and considered them distinct

from other isolations studied. Nos. 126 and 136 are subcultures of the same isolation. No. 137 is perhaps the same isolation as No. 127. Nos. 140 and 141 had probably been interchanged while in culture at Los Banos, P. I., according to Hartley's note. The writer's inoculations indicated that his supposition was correct and the labels were changed accordingly.

Single sporangium, chlamydospore, or hyphal tip cultures were made from all isolations received, except No. 274 (*P. phaseoli*), which was received too late to be included in more than a few growth and pathogenicity experiments.

GROWTH AND REPRODUCTION ON VARIOUS CULTURE MEDIA

The strains were grown on various commonly used culture media to obtain data on mycelial growth and the types and abundance of reproductive organs present after various periods. The media used were steamed corn meal, prepared by moistening 22 g. of yellow corn meal in 125 c. c. Erlenmeyer flasks with 30 c. c. of water; potato dextrose agar (100 g. potato tuber, 20 g. dextrose, 17 g. agar, 1000 c. c. water); oatmeal agar (60 g. ground oatmeal, 17 g. agar, 1000 c. c. water); lima bean agar (60 g. ground lima beans, 17 g. agar, 1000 c. c. water); corn meal agar (60 g. yellow corn meal, 17 g. agar, 1000 c. c. water); steamed green bean pods (short sections of pods in water to one-half their depth in 125 c. c. Erlenmeyer flasks). The oatmeal, lima bean and corn meal agars were not filtered.

The cultures from which transfers to these media were made were two to three weeks old on oatmeal agar. Most of the cultures were kept in diffused light in the laboratory in Porto Rico. Room temperature varied from 24° to 28° C. A few cultures failed to develop at room temperatures, and were kept in an ice chest.

Oatmeal agar proved more satisfactory for early and abundant production of both sporangia and chlamydospores than steamed corn meal or potato dextrose agar. Older cultures sporulated quite freely on lima bean agar, corn meal agar and oatmeal agar, with the last slightly better, fewer cultures failing to produce abundant spores on it than on the other two media. Steamed bean pods proved of little value for the development of reproductive organs, although many cultures made profuse vegetative growth.

In general, cultures of *P. palmivora* produced very little aerial mycelium on steamed corn meal; sporangia and chlamydospores were formed abundantly in young cultures. *P. parasitica* usually made a rather profuse aerial growth on steamed corn meal, but was slower than *P. palmivora* in producing sporangia and chlamydospores, although in

old cultures they were usually abundant, especially chlamydospores. Growth characters are, however, of little importance in distinguishing the two species, since individual cultures often vary. Ashby (9) divided his *P. palmivora* cultures into a typical group (possessing the usual cultural characters), and an atypical group, members of which approached *P. parasitica* in cultural characters. Examination of Table 2 shows this variation distinctly. It would be impossible for anyone who has not made the genus a study to separate the species on the basis of these characteristics. Oogonium formation is often used to distinguish *P. parasitica*, but numerous strains fail to produce them.

P. cactorum, including *P. fagi* and *P. pini*, is more fixed in its characteristics. On steamed corn meal, aerial growth is slight, often resembling frost on the surface of the substratum. Its growth is not very different from typical cultures of *P. palmivora*, but it is easily distinguished by the profuse development of oogonia. *P. cactorum* resembles *P. syringae* rather closely in growth and spore formation. *P. hibernalis* and *P. boehmeriae* resemble *P. cactorum* in macroscopic cultural characters.

P. arecae might be classified as either *P. palmivora* or *parasitica*; *P. colocasiae* resembles *P. palmivora* in growth but produces oogonia; *P. capsici* and *P. hydrophila* are quite similar to *P. parasitica*; *P. cambivora* produces no reproductive bodies; *P. cinnamomi* may be definitely identified by its profuse development of swollen vesicles in clusters (Fig. 10) and the absence of sporangia and oogonia; *P. citrophthora* shows similarities to both *P. palmivora* and *P. parasitica*; *P. citricola* has many characters in common with *P. cactorum*; *P. meadii* is very like some atypical cultures of *P. palmivora*; *P. mexicana* sporulates very sparsely but otherwise resembles *P. parasitica*; *P. cryptogea* is similar to *P. erythroseptica* in appearance and sporulation; *P. nicotianae* can not be distinguished from *P. parasitica*; *P. paeoniae* (No. 243) proves identical, in cultures, with *P. cactorum*; *P. erythroseptica* rarely sporulates and resembles *P. cryptogea* and *P. richardiae*, except for the production of oogonia on oatmeal agar. *P. infestans* and *P. phaseoli* are easily distinguishable by failure to grow on potato dextrose agar in 6 days; *P. richardiae* resembles *P. cryptogea* and *P. erythroseptica*, failing to sporulate on any of the media used at high temperatures. At lower temperatures all produced oogonia on oatmeal agar.

The similarities noted are helpful in obtaining a general notion of the group to which a particular culture belongs, but, except in three instances, insufficient for definite identification.

Three species can be definitely identified: *P. cinnamomi* by the numerous clusters of swollen vesicles, sometimes resembling clusters of

TABLE 2.—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
153	P. arecae	profuse; 1—fairly abundant; zoospores noted; 2—few.	moderate; 1—very few; 2—very few.	moderate; 1—abundant; 2—rare.	moderate; --------- no spores.	1—few; 2—few.	1—few; 2—few.
266	P. boehmeriae	very slight; 1—fairly abundant; 2—fairly abundant; 3—abundant.	moderate; --------- no spores. ---------	very slight; 1—very few; 2—very few; 3—abundant.	slight; 1—abundant; 2—none 3—abundant.	1—fairly abundant; 2—few; 3—fairly abundant;	1—fairly abundant; 2—few; 3—abundant.
192	P. cactorum	slight, frosty; 1—rare; 2—very few; 3—very few.	slight; 1—fairly abundant; 2—few. ---------	slight; 1—rare; 2—fairly abundant; 3—abundant.	slight; 1—fairly abundant; 2—none; 3—abundant.	1—few; 2—few; 3—abundant.	1—few; 2—few; 3—abundant.
194	P. cactorum	slight, frosty; 1—none; 2—abundant; 3—abundant.	slight; 1—fairly abundant; 2—few; 3—rare.	slight; 1—few; 2—fairly abundant; 3—abundant.	slight; 1—very few; 2—none; 3—abundant.	1—very few; 2—rare 3—abundant.	1—abundant; 2—fairly abundant; 3—rare.
179	P. cactorum	slight, frosty; 1—rare; 2—none; 3—abundant.	slight; 1—rare; 2—none; 3—rare.	slight; 1—fairly abundant; 2—few; 3—abundant.	slight; 1—few; 2—fairly abundant; 3—abundant.	1—very few; 2—fairly abundant; 3—abundant.	1—few; 2—fairly abundant; 3—abundant.
184	P. cactorum	slight, frosty; 1—very few; 2—none; 3—abundant.	slight; 1—few; 2—rare; 3—rare.	moderate; 1—few; 2—fairly abundant; 3—fairly abundant.	slight; 1—few; 2—very few; 3—abundant.	1—abundant 2—fairly abundant; 3—abundant.	1—fairly abundant; 2—few; 3—abundant.
189	P. cactorum	slight, frosty; 1—rare; 2—none; 3—abundant.	slight; 1—very few; 2—none; 3—rare.	moderate; 1—fairly abundant; 2—abundant; 3—very few.	slight; 1—fairly abundant; 2—very few; 3—abundant.	1—few; 2—abundant; 3—abundant.	1—few; 2—very few; 3—abundant.
193	P. cactorum	slight, frosty; 1—rare; 2—none; 3—abundant.	slight; 1—rare; 2—rare.	moderate; 1—abundant; 2—few; 3—abundant.	slight; 1—fairly abundant; 2—very few; 3—abundant.	1—few; 2—few; 3—abundant.	1—abundant; 2—none; 3—abundant.
168	P. cactorum	slight, frosty; 1—none; 2—none; 3—few.	moderate; 1—few; 2—few; 3—few.	moderate; 1—very few; 2—few; 3—abundant.	slight; 1—fairly abundant; 2—few; 3—abundant.	1—few; 2—abundant; 3—abundant.	1—abundant; 2—none; 3—abundant.

172	P. cactorum	slight, frosty; 1—rare; 2—few; 3—abundant.	moderate; 1—fairly abundant; 2—very few;	moderate; 1—abundant 2—fairly abundant; 3—few.	slight; 1—fairly abundant; 2—fairly abundant; 3—fairly abundant.	1—very few; 2—few; 3—abundant.	1—abundant; 2—abundant; 3—abundant.
200	P. cactorum	slight, frosty; 1—none; 2—none; 3—abundant.	slight; 1—none; 2—rare;	slight; 1—none; 2—none; 3—very few.	slight; 1—very few; 2—very few; 3—abundant.	1—few; 2—very few; 3—abundant.	1—fairly abundant 2—fairly abundant; 3—abundant.
210	P. cactorum	slight, frosty; 1—none; 2—none; 3—abundant.	slight; 1—very few; 2—very few;	moderate; 1—fairly abundant; 2—rare; 3—fairly abundant.	slight; 1—few; 2—few; 3—abundant.	1—abundant; 2—abundant; 3—abundant.	1—none; 2—abundant; 3—abundant.
190	P. cactorum	slight, frosty; 1—none; 2—none; 3—abundant.	slight; 1—rare; 2—fairly abundant; 3—rare.	slight; 1—rare: 2—fairly abundant; 3—abundant.	slight; 1—rare; 2—very few; 3—abundant.	—rare; 2—very few; 3—abundant.	1—few; 2—abundant; 3—abundant.
243	P. cactorum	slight, frosty; 1—none; 2—few; 3—few.	moderate; 1—none; 2—none; 3—rare.	moderate; 1—very few; 2—very few; 3—abundant.	slight; 1—very few; 2—none: 3—abundant.	1—few; 2—few; 3—abundant.	1—few; 2—very few; 3—abundant.
149	P. cactorum	slight, frosty; 1—rare; 2—very few; 3—very few.	moderate; 1—rare; 2—none: 3—few.	profuse: 1—none; 2—none; 3—abundant.	slight; 1—none; 2—none; 3—abundant.	1—none; 2—none; 3—abundant.	1—none; 2—none; 3—abundant.
160	P. cactorum	slight- frosty; 1—none; 2—few; 3—few.	moderate; 1—none; 2—none; 3—rare.	slight; 1—none; 2—very few: 3—abundant.	slight; 1—none; 2—none: 3—abundant.	1—none; 2—none; 3—abundant.	1—none; 2—very few; 3—abundant.
196	P. cactorum	slight, frosty; 1—none; 2—very few; 3—fairly abundant.	slight; --------- no spores. ---------	slight; 1—very few; 2—few; 3—fairly abundant.	slight; 1—very few; 2—few; 3—abundant.	1—few; 2—none; 3—abundant.	1—none; 2—abundant; 3—abundant.
198	P. cambivora	moderate; --------- no spores.	moderate; --------- no spores.	moderate; --------- no spores.	profuse; --------- no spores.	--------- --------- no spores.	--------- --------- no spores.
208	P. cambivora	moderate; --------- no spores.	moderate --------- no spores.	moderate; --------- no spores.	profuse; --------- no spores.	--------- 1—none; 2—few.	--------- --------- no spores.
147	P. capsici	profuse; --------- no spores. ---------	slight; 1—fairly abundant; 2—none. ---------	profuse; 1—abundant; 2—none. 3—rare.	moderate; 1—abundant; 2—none; 3—rare.	1—abundant; 2—none; ---------	1—abundant; 2—none; 3—very few.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
253	P capsici	moderate; --- no spores. ---	slight; --- no spores. ---	moderate; 1—few; 2—none; 3—rare.	moderate, 1—very few; 2—none; 3—fairly abundant	1—very few; 2—none. ---	1—fairly abundant; 2—none; 3—abundant.
173	P. cinnamomi	slight; 1—none; 2—none.	moderate; 1—none; 2—abundant.	moderate; 1—none; 2—few.	moderate; 1—none; 2—abundant.	1—none; 2—abundant.	1—none; 2—abundant.
174	P. cinnamomi	slight; 1—none; 2—few	moderate; 1—none; 2—abundant.	moderate; 1—none; 2—fairly abundant.	moderate; 1—none; 2—abundant.	1—none; 2—abundant.	1—none; 2—abundant.
195	P. cinnamomi	slight; 1—none; 2—few.	moderate; 1—none; 2—abundant.	moderate; 1—none; 2—few.	moderate; 1—none; 2—abundant.	1—none; 2—abundant.	1—none; 2—abundant.
242	P. cinnamomi	slight; 1—none; 2—few.	moderate; 1—none; 2—few.	moderate; 1—none; 2—few.	profuse; 1—none; 2—abundant.	1—none; 2—abundant.	1—none; 2—few.
244	P. cinnamomi	moderate; 1—none; 2—few.	moderate; 1—none; 2—fairly abundant.	moderate; 1—none; 2—few.	profuse; 1—none; 2—abundant.	1—none; 2—abundant.	1—none; 2—fairly abundant.
267	P. citricola	slight, frosty; 1—none; 2—very few; 3—fairly abundant.	slight; 1—none; 2—very few. ---	moderate; 1—none; 2—none; 3—abundant.	moderate; 1—none; 2—very few; 3—abundant.	1—none; 2—none; 3—abundant.	1—rare; 2—none; 3—abundant.
154	P. citrophthora	slight; --- no spores.	moderate; --- no spores.	profuse; 1—very few; 2—abundant.	moderate; 1—few; 2—few.	1—few; 2—fairly abundant.	1—rare; 2—very few.
221	P. citrophthora	moderate; --- no spores.	moderate; 1—none; 2—very few.	profuse; 1—very few; 2—fairly abundant.	moderate; --- no spores.	1—very few; 2—fairly abundant.	1—few; 2—few.
222	P. citrophthora	moderate; --- no spores;	moderate; 1—very few; 2—fairly abundant.	profuse; 1—abundant; 2—very few.	moderate; 1—none; 2—rare.	1—few; 2—abundant.	1—abundant; 2—fairly abundant.

152	P. colocasiae	slight, frosty; 1—abundant; 2—abundant.	moderate; no spores.	moderate; 1—fairly abnndant; 2—few.	slight 1—fairly abundant; 2—few. 3—few.	1—fairly abundant; 2—few.	1—abundant; 2—abundant; 3—abundant.
239	P. colocasiae	slight, frosty; 1—abundant; 2—none.	moderate; 1—very few; 2—abundant.	moderate; 1—abundant; 2—few; 3—rare.	slight; 1—abundant; 2—very few; 3—very few.	1—abundant; 2—none; 3—very few.	—abundant; 2—fairly abundant; 3—few.
150	P. cryptogea	slight; no spores.	slight; no spores.	profuse; no spores.	profuse; no spores.	no spores.	1—none; 2—fairly abundant.
176	P. erythroseptica	slight; no spores.	moderate; no spores.	moderate; no spores.	moderate; no spores.	1—none; 2—rare.	1—none; 2—none; 3—abundant.
246	P. hibernalis	*slight, frosty; 1—none; 2—none; 3—fairly abundant.	**slight; no spores.	*slight, frosty; 1—rare; 2—none; 3—fairly abundant.	**slight; 1—none; 2—none; 3—abundant.	**1—abundant; 2—none; 3—abundant.	**1—none; 2—none. 3—abundant.
241	P. hydrophila	moderate; no spores.	moderate; no spores.	moderate; 1—fairly abundant; 2—none. 3—few	moderate; 1—very few; 2—none.	1—few; 2—none.	1—few; 2—none; 3—abundant.
245	P. infestans	*slight, frosty; 1—abundant; 2—none.	*no growth	**slight; 1—few; 2—none.	*slight; 1—very few; 2—none.	**1—fairly abundant; 2—none.	**1—fairly abundant; 2—none.
248	P. infestans	*slight, frosty; 1—abundant. 2—none.	*no growth.	**slight; 1—rare. 2—none; 3—few.	*slight; 1—very few; 2—none.	*1—abundant; 2—none.	*1—fairly abundant. 2—none. 3—rare.
223	P. meadii	moderate; 1—none; 2—rare.	moderate; no spores.	moderate; 1—abundant; 2—rare.	moderate; 1—rare; 2—none.	1—few; 2—few.	1—abundant; 2—rare.
238	P. meadii	moderate; 1—none; 2—rare.	slight; no spores.	moderate; 1—few; 2—none.	profuse; no spores.	1—few; 2—none.	1—rare; 2—rare.
257	P. meadii	moderate; no spores.	moderate; no spores.	profuse; 1—abundant; 2—very few.	moderate; 1—few; 2—few.	1—abundant; 2—very few.	1—few; 2—very few.

*4 weeks at 10 degrees Centigrade **At 10 degrees Centigrade.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
148	P. mexicana	moderate; no spores.	moderate; 1—very few; 2—very few.	moderate; 1—none; 2—very few; 3—fairly abundant.	moderate; 1—none; 2—rare.	1—rare; 2—none.	1—none; 2—none; 3—few.
216	P. nicotianae	profuse; no spores.	moderate; 1—very few; 2—fairly abundant.	moderate; 1—very few; 2—abundant.	profuse; 1—rare; 2—abundant.	1—abundant; 2—abundant.	1—few; 2—abundant; 3—very few.
232	P. nicotianae	profuse; 1—none; 2—few.	moderate; 1—few; 2—fairly abundant.	profuse; 1—few; 2—abundant.	profuse; 1—few; 2—fairly abundant.	1—none; 2—abundant.	1—few; 2—abundant.
247	P. nicotianae	profuse; 1—rare; 2—few.	moderate; 1—fairly abundant; 2—fairly abundant.	profuse; 1—few; 2—fairly abundant; 3—few.	profuse; 1—few; 2—abundant.	1—few; 2—abundant.	1—very few; 2—abundant.
271	P. palmivora (typ.)	slight, frosty; 1—fairly abundant; 2—abundant.	moderate; 1—none; 2—very few.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.		1—fairly abundant; 2—abundant.
12	P. palmivora (typ.)	slight, frosty; 1—few; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—fairly abundant.	moderate; 1—very few; 2—abundant.	1—few; 2—abundant.	1—few; 2—abundant.
123	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; 1—few; 2—abundant.	profuse; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—few. 2—abundant.
236	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; 1—fairly abundant; 2—fairly abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
13	P. palmivora (typ.)	slight, frosty; 1—fairly abundant; 2—abundant.	profuse; 1—very few; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—few; 2—abundant.	1—fairly abundant; 2—abundant.	1—fairly abundant; 2—abundant.
127	P. palmivora (typ.)	slight, frosty; 1—abundant. 2—abundant.	moderate; 1—few; 2—abundant.	profuse; 1—abundant; 2—abundant.	profuse; 1—abundant; 2—abundant.	1—abundant; 2—very few.	1—few; 2—abundant.
137	P. palmivora (typ.)	slight, frosty; 1—few; 2—abundant.	profuse; no spores.	profuse; 1—fairly abundant; 2—abundant.	profuse; 1—abundant; 2—abundant.	1—very few; 2—rare.	1—very few; 2—abundant.

249	P. palmivora (typ.)	moderate; 1—abundant; 2—fairly abundant.	moderate; 1—fairly abundant; 2—very few.	moderate; 1—abundant; 2—fairly abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—fairly abundant.
250	P. palmivora (typ.)	moderate; 1—abundant; 2—abundant.	moderate; 1—fairly abundant; 2—few.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—fairly abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
265	P. palmivora (typ.)	moderate; 1—abundant; 2—abundant.	moderate; 1—none; 2—fairly abundant.	slight; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—fairly abundant	1—abundant; 2—abundant.
1	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	profuse; 1—fairly abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—few; 2—abundant.	1—fairly abundant; 2—abundant.	1—very few; 2—abundant.
3	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; 1—rare; 2—rare.	moderate; 1—abundant; 2—few.	moderate; 1—fairly abundant; 2—fairly abundant.	1—abundant; 2—few.	1—abundant; 2—fairly abundant.
17	P. palmivora (typ.)	slight, frosty; 1—fairly abundant; 2—few.	profuse; 1—rare; 2—very few.	profuse; 1—fairly abundant; 2—fairly abundant.	profuse; 1—none; 2—abundant.	1—very few; 2—abundant.	1—few; 2—fairly abundant.
16	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—few.	moderate; 1—few; 2—few.	moderate; 1—abundant; 2—few.	moderate; 1—fairly abundant; 2—abundant.	1—abundant; 2—abundant.	
9	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; --------- no spores.	moderate; 1—abundant; 2—few.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—fairly abundant.
14	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—fairly abundant.	slight; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
272	P. palmivora (typ.)	moderate; 1—fairly abundant; 2—few.	slight; 1—few; 2—very few.	slight; --------- ---------	slight; 1—few; 2—rare.		
235	P. palmivora (typ.)	slight, frosty; 1—fairly abundant; 2—few.	moderate; ------ -- no spores.	moderate; 1—none; 2—rare.	moderate; 1—none; 2—rare.	1—very few; 2—none.	1—fairly abundant; 2—none.
146	P. palmivora (typ.)	slight, frosty; 1—few; 2—abundant.	profuse; 1—fairly abundant; 2—abundant.	slight; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—fairly abundant; 2—abundant.	1—fairly abundant; 2—abundant.
4	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—fairly abundant; 2—abundant.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
5	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	slight; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—fairly abundant; 2—abundant.	1—abundant; 2—abundant.
7	P. palmivora (typ.)	slight, frosty; 1—abundant; 2—abundant.	slight; 1—abundant; 2—abundant.	slight; no spores.	moderate; 1—very few; 2—abundant.	1—abundant; 2—abundant.	1—none; 2—abundant.
255	P. palmivora (atyp.)	moderate; 1—few; 2—abundant.	moderate; 1—few; 2—fairly abundant.	profuse; 1—abundant; 2—abundant.	profuse; 1—few; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
180	P. palmivora (atyp.)	moderate; --------- no spores.	moderate; 1—very few; 2—fairly abundant.	moderate; 1—fairly abundant; 2—abundant.	moderate; 1—rare; 2—abundant.	1—very few; 2—abundant.	1—few; 2—abundant.
126	P. palmivora (atyp.)	slight, frosty; 1—very few; 2—abundant.	profuse; 1—rare; 2—few.	profuse; 1—few; 2—abundant.	moderate; 1—fairly abundant; 2—fairly abundant.	1—few; 2—abundant.	1—few; 2—abundant.
136	P. palmivora (atyp.)	slight; 1—none; 2—abundant.	profuse; --------- no spores.	profuse; 1—none; 2—few.	moderate; 1—few; 2—fairly abundant.	1—fairly abundant; 2—abundant.	1—none; 2—abundant.
97	P. palmivora (atyp.)	slight; --------- no spores.	slight; 1—rare; 2—few.	profuse; 1—fairly abundant; 2—very few.	profuse; 1—very few; 2—none.	1—abundant; 2—abundant.	1—fairly abundant; 2—fairly abundant.
102	P. palmivora (atyp.)	slight; --------- no spores.	slight; 1—rare; 2—few.	profuse; 1—very few; 2—none.	profuse; --------- no spores.	1—few; 2—few.	no spores.
116	P. palmivora (atyp.)	moderate; 1—rare; 2—none.	moderate; --------- no spores.	slight; --------- no spores.	slight; --------- no spores.	1—abundant; 2—very few.	no spores.
140	P. palmivora (atyp.)	profuse; 1—none. 2—few.	profuse; 1—none. 2—few.	profuse; 1—abundant; 2—abundant.	moderate; 1—fairly abundant; 2—abundant.	1—fairly abundant; 2—abundant.	1—very few; 2—abundant.
15	P. palmivora (atyp.)	moderate; 1—none; 2—rare.	moderate; 1—rare; 2—few.	profuse; 1—few; 2—abundant.	profuse; 1—very few; 2—abundant.	1—fairly abundant; 2—abundant.	1—very few; 2—abundant.

138 P. palmivora (atyp.)	slight, frosty; 1—very few; 2—abundant.	slight; 1—rare; 2—abundant.	slight; 1—abundant; 2—abundant.	moderate; 1—few; 2—abundant.	1—abundant; 2—few.	1—few; 2—abundant.
18 P. palmivora (atyp.)	slight; --- no spores.	moderate; --- no spores.	moderate; --- no spores.	moderate; 1—fairly abundant; 2—few.	1—few; 2—rare.	1—few; 2—few.
22 P. palmivora (atyp.)	moderate; --- no spores.	slight; 1—rare; 2—none.	profuse; 1—abundant; 2—few.	profuse; 1—fairly abundant; 2—few.	1—abundant; 2—abundant.	1—abundant; 2—fairly abundant.
26 P. palmivora (atyp.)	moderate; 1—abundant; 2—few.	slight; 1—abundant; 2—rare.	moderate; 1—fairly abundant; 2—few.	moderate; 1—rare; 2—none.	1—few; 2—rare.	1—rare; 2—none.
36 P. palmivora (atyp.)	moderate; --- no spores.	slight; --- no spores.	profuse; 1—abundant; 2—few.	profuse; 1—rare; 2—rare.	1—very few; 2—none.	1—very few; 2—rare.
44 P. palmivora (atyp.)	moderate; --- no spores.	slight; --- no spores.	moderate; 1—fairly abundant; 2—very few.	profuse; 1—few; 2—few.	--- no spores.	1—few; 2—rare.
100 P. palmivora (atyp.)	slight; --- no spores.	slight; --- no spores.	profuse; 1—abundant; 2—few.	profuse; 1—very few; 2—fairly abundant.	1—few; 2—rare.	1—very few; 2—very few.
121 P. palmivora (atyp.)	slight; --- no spores.	slight; --- no spores.	profuse; 1—abundant; 2—abundant.	profuse; 1—none; 2—abundant.	1—rare; 2—none.	1—very few; 2—abundant.
6 P. palmivora (atyp.)	slight, frosty; 1—few; 2—few.	profuse; 1—few; 2—few.	moderate; 1—very few; 2—fairly abundant.	profuse; 1—none; 2—few.	1—very few; 2—abundant.	1—few; 2—fairly abundant.
130 P. palmivora (atyp.)	moderate; --- no spores.	slight; 1—very few; 2—rare.	moderate; 1—abundant; 2—very few.	profuse; 1—rare; 2—none.	1—fairly abundant; 2—few.	
141 P. palmivora (atyp.)	moderate; --- no spores.	moderate; --- no spores.	proruse; 1—very few; 2—none.	moderate; --- no spores.	1—abundant; 2—abundant.	1—few; 2—very few.
254 P. palmivora (atyp.)	moderate; 1—few; 2—abundant.	moderate; 1—few; 2—fairly abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
185 P. parasitica	profuse; --- no spores.	slight; 1—rare; 2—very few.	moderate; 1—fairly abundant; 2—fairly abundant.	moderate; 1—very few; 2—fairly abundant.	1—none; 2—very few.	1—fairly abundant; 2—abundant.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
228	P. parasitica	profuse; 1—few; 2—few.	profuse; 1—fairly abundant; 2—few.	moderate; 1—abundant; 2—abundant.	profuse; 1—abundant; 2—abundant.	1—few; 2—abundant.	1—abundant; 2—abundant.
268	P. parasitica	profuse; 1—none; 2—few.	moderate; 1—fairly abundant; 2—few.	moderate; 1—few; 2—fairly abundant.	profuse; 1—few; 2—abundant.	--------- ---------	1—abundant; 2—abundant.
183	P. parasitica	profuse; 1—rare; 2—fairly abundant; 3—few.	profuse; 1—few; 2—abundant. ---------	profuse; 1—abundant; 2—abundant. ---------	profuse; 1—rare; 2—abundant. ------ --	1—very few; 2—abundant. ---------	1—abundant; 2—abundant. ---------
209	P. parasitica	profuse; 1—rare; 2—fairly abundant; 3—few.	profuse; 1—rare; 2—abundant. ------ --	profuse; 1—fairly abundant; 2—few. ---------	profuse; 1—few; 2—fairly abundant. ---------	1—rare; 2—abundant. -- - ----	1—few; 2—abundant. ---------
260	P. parasitica	profuse; 1—very few 2—few. -------	slight 1—few; 2—fairly abundant. ---------	profuse; 1—fairly abundant; 2—abundant; 3—fairly abundant.	moderate; 1—very few 2—abundant ---------	1—few; 2—abundant. --------	1—abundant; 2—abundant; 3—few.
269	P. parasitica	profuse --------- no spores. ---------	very slight ------- no spores. ----- --	--------- 1—very few; 2—abundant; 3—abundant	moderate 1—fairly abundant; 2—abundant; 3—few	--------- --------- ---------	1—fairly abundant; 2—abundant; 3—fairly abundant.
144	P. parasitica	moderate 1—rare; 2—abundant. ---------	moderate; 1—few; 2—few. -------	moderate 1—very few 2—abundant. ---------	profuse; 1—none; 2—fairly abundant -------	1—rare 2—abundant --------	1—rare 2—abundant 3—rare.
178	P. parasitica	profuse; --------- no spores ---------	moderate; 1—none; 2—few ---------	moderate; 1—fairly abundant; 2—abundant ---------	profuse 1—very few; 2—abundant. ---------	1—very few; 2—abundant ---------	1—none; 2—abundant. 3—few.
2	P. parasitica	profuse; 1—fairly abundant; 2—few. ---------	profuse; 1—none; 2—few. ---------	profuse; 1—very few 2—few; 3—rare	profuse; ------- no spores. -------	1—rare 2—abundant. ---------	1—none; 2—abundant 3—rare.
8	P. parasitica	--------- 1 none; 2—fairly abundant.	--------- 1—none; 2—few.	moderate; 1—fairly abundant; 2—abundant	profuse; 1—few; 2—fairly abundant.	1—few; 2—few.	1—very few; 2—abundant.

10 P. parasitica	profuse; 1—rare; 2—fairly abundant.	slight; 1—fairly abundant; 2—fairly abundant.	profuse; 1—fairly abundant; 2—abundant; 3—very few	profuse; 1—none; 2—abundant.	1—rare; 2—abundant.	1—fairly abundant; 2—abundant. 3—fairly abundant
11 P. parasitica	profuse; 1—few; 2—fairly abundant.	slight; 1—fairly abundant. 2—fairly abundant.	profuse; 1—abundant; 2—abundant.	profuse; 1—abundant; 2—abundant.	1—very few; 2—abundant.	
258 P. parasitica	profuse; no spores.	moderate; 1—very few; 2—very few.	profuse; 1—very few; 2—few.	profuse; no spores.	1—rare; 2—abundant.	1—few; 2—abundant.
142 P. parasitica	moderate; no spores.	moderate; 1—few; 2—rare.	moderate; 1—none; 2—few.	profuse; 1—very few; 2—few.	1—few; 2—abundant.	1—fairly abundant; 2—abundant.
261 P. parasitica	profuse; 1—few; 2—fairly abundant.	moderate; 1—very few; 2—few.	profuse; 1—abundant; 2—abundant; 3—abundant.	profuse; 1—very few; 2—abundant.	1—very few; 2—abundant.	1—abundant; 2—abundant.
262 P. parasitica	profuse; 1—rare; 2—very few.	moderate; 1—few; 2—fairly abundant.	moderate; 1—abundant; 2—abundant.	moderate; 1—abundant; 2—abundant.	1—very few; 2—abundant.	
165 P. parasitica	profuse; 1—rare; 2—very few.	slight; 1—few; 2—fairly abundant.	profuse; 1—few; 2—abundant.	moderate; 1—none; 2—very few.	1—rare; 2—abundant.	1—none; 2—abundant; 3—abundant.
211 P. parasitica	moderate; no spores.	slight; 1—rare; 2—rare.	moderate; 1—fairly abundant; 2—few; 3—fairly abundant.	moderate; 1—few; 2—fairly abundant.	1—very few; 2—abundant; 3—few.	1—fairly abundant; 2—abundant; 3—fairly abundant.
212 P. parasitica	moderate; no spores.	slight; 1—none; 2—few.	moderate; 1—none; 2—few; 3—few.	moderate; 1—few; 2—fairly abundant.	1—none; 2—abundant.	1—fairly abundant; 2—abundant; 3—abundant.
270 P. parasitica	moderate; 1—none; 2—very few.	moderate; 1—few; 2—abundant.	1—fairly abundant; 2—abundant; 3—rare.	moderate; 1—fairly abundant; 2—abundant.		1—fairly abundant; 2—abundant.
132 P. parasitica	profuse; 1—few; 2—abundant; 3—rare.	moderate; 1—fairly abundant; 2—few.	profuse; 1—abundant; 2—abundant; 3—abundant.	profuse; 1—abundant; 2—abundant.	1—abundant; 2—abundant; 3—abundant.	1—fairly abundant; 2—abundant; 3—very few.
162 P. parasitica	profuse; no spores.	moderate; 1—very few; 2—fairly abundant.	profuse; 1—fairly abundant; 2—fairly abundant.	profuse; 1—few; 2—abundant.	1—rare; 2—abundant.	1—fairly abundant; 2—abundant.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
177	P. parasitica	profuse --- no spores. --- ---	moderate; 1—very few; 2—abundant; 3—rare.	moderate; 1—fairly abundant; 2—abundant. ---	profuse; 1—none; 2—few; 3—fairly abundant.	1—abundant; 2—abundant; 3—rare.	1—few; 2—abundant.
181	P. parasitica	profuse; 1—few; 2—fairly abundant; 3—few.	profuse; 1—few; 2—abundant. --- ---	profuse; 1—abundant; 2—abundant. ---	profuse; 1—few; 2—abundant. ---	1—very few; 2—abundant. ---	1—few; 2—abundant. 3—rare.
186	P. parasitica	profuse; 1—none; 2—rare; ---	moderate; 1—few; 2—few. ---	profuse; 1—few; 2—very few; 3—rare.	moderate; 1—very few; 2—abundant.	1—few; 2—abundant.	1—rare; 2—abundant.
187	P. parasitica	profuse; 1—rare; 1—few.	moderate; 1—very few; 2—fairly abundant.	moderate; 1—few; 2—abundant.	profuse; 1—few; 2—abundant.	1—rare; 2—abundant.	1—rare; 2—abundant.
191	P. parasitica	profuse; 1—very few; 2—abundant.	moderate; 1—very few; 2—abundant.	profuse; 1—fairly abundant; 2—abundant.	profuse; 1—very few; 2—abundant.	1—very few; 2—abundant.	
251	P. parasitica	profuse; --- --- no spores.	moderate; 1—few; 2—few.	profuse; 1—abundant; 2—abundant.	profuse; 1—fairly abundant; 2—abundant.	1—few; 2—abundant.	1—abundant; 2—abundant.
264	P. parasitica	profuse; 1—rare; 2—very few.	moderate; 1—few; 2—few.	profuse; 1—abundant; 2—fairly abundant.	moderate; 1—none; 2—few.	1—few; 2—very few.	1—very few; 2—abundant.
143	P. parasitica	profuse; --- no spores. --- --	moderate; 1—none. 2—rare. - ---	profuse; 1—none. 2—few. 3—rare.	profuse; --- no spores. ---	1—abundant; 2—abundant; 3—abundant.	1—very few; 2—abundant; 3—rare.
217	P. parasitica	slight; --- no spores.	moderate; 1—none; 2—very few.	moderate; 1—none; 2—fairly abundant.	slight; 1—rare; 2—rare.	1—rare; 2—fairly abundant.	1—very few; 2—few.
259	P. parasitica	profuse; 1—very few; 2—none. - ---	moderate; 1—few; 2—few. ---	profuse; 1—abundant; 2—abundant; 3—fairly abundant.	moderate; 1—none; 2—few. ---	1—very few; 2—abundant. ---	1—few; 2—abundant; 3—few.

159 P. parasitica	profuse; 1—none; 2—very few.	slight; 1—very few; 2—fairly abundant.	moderate; 1—very few; 2—abundant.	moderate; 1—very few; 2—abundant. 3—rare.	1—none; 2—fairly abundant.	1—none; 2—abundant.
169 P. parasitica	profuse; 1—none. 2—rare.	moderate; 1—abundant; 2—few.	profuse; 1—few; 2—few.	profuse; 1—very few; 2—fairly abundant.	1—abundant; 2—abundant.	1—fairly abundant; 2—abundant.
175 P. parasitica	profuse; 1—rare; 2—fairly abundant.	moderate; 1—few; 2—fairly abundant.	profuse; 1—none; 2—abundant.	profuse; 1—few; 2—abundant.	1—very few; 2—abundant.	1—very few; 2—abundant. 3—very few.
204 P. parasitica	profuse; 1—none; 2—abundant.	moderate; 1—none; 2—few.	slight; no spores.	moderate; 1—fairly abundant; 2—abundant.	1—very few; 2—abundant.	1—few; 2—abundant; 3—rare.
234 P. parasitica	profuse; 1—rare; 2—rare.	moderate; 1—very few; 2—fairly abundant.	profuse; 1—rare; 2—fairly abundant.	profuse; 1—few; 2—fairly abundant.	1—few; 2—abundant.	1—very few; 2—abundant.
139 P. parasitica	profuse; no spores.	slight; 1—fairly abundant; 2—very few.	profuse; 1—abundant; 2—abundant; 3—abundant.	profuse; 1—abundant; 2—abundant.	1—abundant; 2—abundant; 3—few.	1—fairly abundant; 2—abundant; 3—fairly abundant.
161 P. parasitica	moderate; 1—none; 2—rare.	moderate; 1—few. 2—few.	moderate; 1—abundant; 2—very few.	profuse; 1—very few; 2—very few.	1—rare; 2—fairly abundant.	1—abundant; 2—abundant; 3—very few.
182 P. parasitica	profuse; 1—rare; 2—fairly abundant; 3—abundant.	profuse; 1—rare; 2—fairly abundant.	profuse; 1—few; 2—abundant.	profuse; 1—very few; 2—abundant.	1—very few; 2—abundant.	1—few; 2—abundant.
201 P. parasitica	profuse; 1—none; 2—rare.	moderate; 1—rare; 2—rare.	moderate; 1—fairly abundant; 2—few; 3—abundant.	profuse; 1—few; 2—fairly abundant.	1—few; 2—abundant; 3—very few.	1—none; 2—abundant; 3—abundant.
202 P. parasitica	profuse; 1—none; 2—rare.	moderate; 1—none; 2—rare.	profuse; 1—very few; 2—fairly abundant 3—rare.	profuse; 1—none; 2—very few.	1—few; 2—abundant; 3—rare.	1—few; 2—abundant; 3—very few.
213 P. parasitica	profuse; 1—none; 2—few.	profuse; 1—none; 2—rare.	moderate; 1—very few; 2—very few; 3—abundant.	profuse; 1—rare; 2—fairly abundant; 3—fairly abundant.	1—few; 2—abundant; 3—rare.	1—few; 2—fairly abundant; 3—fairly abundant.

TABLE 2 (CONTINUED).—PRODUCTION OF AERIAL MYCELIUM AND REPRODUCTIVE ORGANS ON CULTURE MEDIA

No.	Species	Steamed corn meal 2 wks.	Potato dextrose agar 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.
252	P. parasitica	profuse; 1—none; 2—rare.	moderate; 1—very few; 2—very few.	moderate; 1—rare; 2—abundant.	profuse; 1—very few; 2—none.	1—none; 2—rare.	1—very few; 2—fairly abundant.
197	P. parasitica	profuse; 1—rare; 2—fairly abundant.	moderate; 1—none; 2—few.	moderate; 1—very few; 2—abundant.	moderate; 1—few 2—abundant.	1—very few; 2—abundant.	1—very few; 2—abundant.
203	P. parasitica	profuse; 1—rare; 2—very few.	profuse; 1—none; 2—few.	profuse; 1—rare; 2—few.	profuse; 1—none; 2—few.	1—very few; 2—abundant.	1—very few; 2—fairly abundant.
207	P. parasitica	moderate; 1—rare; 2—abundant. ---------	slight; 1—very few; 2—very few. ---------	profuse; 1—abundant; 2—abundant; 3—very few.	moderate; 1—few; 2—fairly abundant. ---------	1—few; 2—abundant; 3—rare.	1—very few; 2—abundant; 3—fairly abundant.
145	P. parasitica	moderate; 1—none; 2—few. ---------	moderate; 1—none; 2—fairly abundant. ---------	profuse; 1—few; 2—few. ---------	profuse; 1—none; 2—abundant. ---------	1—few; 2—abundant. ---------	1—abundant; 2—abundant; 3—few.
263	P. parasitica	profuse; 1—few; 2—fairly abundant. ---------	moderate; 1—very few; 2—fairly abundant. ---------	profuse; 1—abundant; 2—abundant; 3—abundant.	profuse; 1—very few; 2—abundant; 3—very few.	1—few; 2—fairly abundant. ---------	1—abundant; 2—abundant; 3—few.
151	P. parasitica	profuse; 1—fairly abundant; 2—fairly abundant.	moderate; 1—fairly abundant; 2—abundant.	moderate; 1—fairly abundant; 2—fairly abundant.	profuse; 1—abundant; 2—abundant.	1—abundant; 2—abundant.	1—abundant; 2—abundant.
164	P parasitica	profuse; 1—rare 2—rare -------	slight; 1—rare; 2—few. -------	profuse; 1—few; 2—abundant ---------	profuse; 1—abundant; 2—abundant ---------	1—very few; 2—abundant; 3—rare	1—few 2—abundant -------
166.	P. parasitica	profuse; --------- no spores.	slight; 1—few; 2—very few.	profuse; 1—fairly abundant; 2—abundant.	profuse; 1—few; 2—fairly abundant.	1—very few; 2—abundant.	1—abundant; 2—abundant.
167	P. parasitica	profuse; --------- no spores.	profuse; 1—rare; 2—few.	profuse; 1—very few; 2—abundant.	profuse; 1—very few; 2—abundant.	1—very few; 2—abundant.	1—fairly abundant; 2—abundant.

171	P. parasitica	profuse; --- no spores.	moderate; 1—very few; 2—abundant.	moderate; 1—fairly abundant; 2—fairly abundant.	moderate; 1—few; 2—few.	1—very few; 2—abundant.	1—abundant; 2—abundant.
199	P. parasitica	moderate; 1—none; 2—rare. ---	moderate; 1—rare; 2—few. ---	moderate; 1—very few; 2—abundant. ---	moderate; 1—none; 2—few. ---	1—very few; 2—abundant. ---	1—none; 2—abundant; 3—very few.
205	P. parasitica	moderate; 1—rare; 2—few. ---	moderate; 1—few; 2—abundant. ---	profuse; 1—few; 2—abundant. ---	moderate; 1—few; 2—abundant. ---	1—very few; 2—abundant. ---	1—none; 2—abundant; 3—few.
274	P. phaseoli	--- --- --- ---	--- *no growth --- ---	--- --- --- ---	*moderate; 1—fairly abundant; 2—none; 3—abundant.		
227	P. richardiae	slight; --- no spores.	moderate; --- no spores.	slight; --- no spores.	profuse; --- no spores.	no spores.	no spores.
156	P. syringae	*slight, frosty; 1—none; 2—none; 3—fairly abundant.	*slight; --- no spores. ---	**moderate; 1—none; 2—none; 3—few.	*slight; 1—none; 2—none; 3—abundant.	*1—none; 2—none; 3—abundant.	
230	P. syringae	*slight, frosty; 1—none; 2—none; 3—fairly abundant.	*slight; --- no spores. ---	**moderate; 1—none; 2—none; 3—fairly abundant.	*slight; 1—none; 2—none; 3—abundant.	*1—none; 2—none; 3—abundant.	
206	P. drechsleri	profuse; --- no spores. ---	profuse; --- no spores. ---	moderate; 1—none; 2—few. ---	moderate; 1—rare; 2—rare. ---	no spores. --- ---	1—few; 2—none; 3—few.

*4 weeks at 10°C. **At 10°C.

grapes, and the absence of other types of spores. The vesicles are produced singly as well as in clusters, and may resemble chlamydospores, but their lobed or branched character is characteristic in oatmeal agar, corn meal agar and lima bean agar cultures (Fig. 10). *P. infestans* and *P. phaseoli* fail to grow on potato dextrose agar. *P. thalictri* probably belongs here also, in view of Leonian and Geer's (119) failure to obtain growth on malt extract agar, and the general similarity between the

Fig. 10.—*P. cinnamomi* (No. 173). Swollen vesicles, sometimes resembling chlamydospores, from an oat meal agar culture one month old. (x400).

three species. Unfortunately, the writer was unable to obtain a culture of *P. thalictri*. *P. phaseoli* produces oospores abundantly on oatmeal agar and is easily separated from *P. infestans* which produces them very slowly and sparsely, if at all.

P. drechsleri produces a few non-papillate sporangia but their rarity prevents use of this characteristic. It resembles *P. erythroseptica* in general growth characters.

In Table 2 some species are considered synonymous and combined with others; e. g. *P. pini*, *P. fagi* and No. 243 (*P. paeoniae?*) are treated as *P. cactorum*. *P. parasitica* includes cultures received as *P. terrestris*. *P. terrestris var. rhei*, *P. parasitica var. lycopersici* and *P. melongenae*. *P. palmivora* includes *P. faberi*. Further combinations or divisions of species, as well as reasons for the classification of cultures used in Table 2, will be reserved for a discussion of taxonomy.

MORPHOLOGICAL OBSERVATIONS

Sporangia

Measurements of the lengths and greatest diameters of 400 sporangia were made when they were borne fairly abundantly on any of the media used. All measurements of sporangia of typical cultures of *P. palmivora* are from cultures two weeks old on steamed corn meal. Cultures of *P. palmivora* which produce much aerial mycelium or few sporangia on this medium in two weeks are classed as atypical. Measurements for cultures which failed to sporulate freely on corn meal were obtained from cultures 4 months old on lima bean agar and oatmeal agar, or 6 months old on corn meal agar. Some isolations of *P. palmivora* are intermediate in character and may be considered either typical or atypical.

Comparative measurements of sporangia of the same isolation on different media indicate that those produced on a substratum on which their production is partially suppressed are smaller than sporangia from cultures in which they develop more freely. No single medium seems most favorable for sporangium formation; different isolations of the same species show decided variations, a particular isolation sometimes producing sporangia sparsely on a medium which is quite favorable to sporulation with other conspecific isolations. Measurements were made from media favorable to sporangium development.

The extreme and average measurements for abundantly sporulating isolations are listed in Table 3. It will be noted in the column of "Extremes" that the small extremes are even numbers and the large extremes odd. When the measurements were made they were grouped, as to length and diameter, in biometric classes. Subsequently it was found that the dimensions are not of sufficient significance to warrant the presentation of a large number of tables. In condensing the data fractions have been disregarded. An isolation whose extreme lengths fall into the classes 17.5-19.49μ and 71.5-73.49μ will appear in Table 3 as "Extremes 18-73," etc. Chlamydospore measurements will be handled in the same manner.

The calculated means and probable errors are omitted as their use does not increase the significance or usefulness of these data.

Wide variations in the dimensions of sporangia occur within species. The typical cultures of *P. palmivora* produce much longer sporangia than some other species, yet certain atypical cultures of the former have sporangia smaller than any culture of *P. cactorum*. Sporangia of *P. parasitica* and *P. palmivora* are so widely variable in size that no other species can be separated from them by this character alone.

TABLE 3.—EXTREME AND AVERAGE DIMENSIONS OF 400 SPORANGIA OF 11 SPECIES OF PHYTOPHTHORA. MEASUREMENTS IN MICRA.

No.	Species	Host	Extremes	Average
153	P. arecae	Areca catechu	18-43x14-33	33.93x24.78
266	P. boehmeriae	Boehmeria nivea	28-69x20-51	51.77x40.08
192	P. cactorum	Fagus sp.	20-51x14-29	31.90x22.55
194	" "	Lilium candidum	16-39x12-29	26.05x21.20
179	" "	Pyrus malus	20-43x16-31	29.72x21.87
184	" "	" "	18-39x14-25	26.22x20.71
189	" "	" "	20-49x14-31	30.73x21.95
193	" "	" "	20-51x18-39	34.07x25.72
168	" "	Rheum Rhaponticum	20-47x16-33	32.40x24.05
172	" "	Unknown	18-37x14-29	26.89x22.71
200	" "	"	18-55x14-33	33.90x22.88
210	" "	"	16-47x14-27	32.06x24.05
147	P. capsici	Capsicum annuum	16-69x12-31	30.01x20.81
253	" "	" "	24-59x18-41	37.91x27.05
222	P. citrophthora	Citrus sp.	27-57x18-33	37.70x23.55
152	P. colocasiae	Caladium Colocasia	20-70x14-39	36.97x21.18
239	" "	" "	22-53x16-35	34.24x22.71
245	P. infestans	Solanum tuberosum	22-55x16-31	35.58x22.04
248	" "	" "	22-59x14-29	37.91x21.88
223	P. meadii	Hevea brasiliensis	26-87x20-45	48.09x32.90
257	" "	Vanilla Vanilla	20-57x16-33	32.73x23.88
216	P. nicotianae	Nicotiana tabacum	18-61x14-39	35.07x25.22
271	P. palmivora (typical)	Antirrhinum majus	24-73x18-37	51.10x30.56
12	" "	Artocarpus incisa	28-73x18-39	48.10x28.89
123	" "	Borassus flabellifer	28-93x20-43	60.52x31.78
236	" "	" "	26-79x20-43	49.10x31.40
13	" "	Carica papaya	32-91x20-39	50.80x29.73
127	" "	" "	24-67x16-37	41.75x25.77
137	" "	" "	26-57x20-37	40.18x28.29
249	" "	Citrus sp.	22-71x16-39	38.91x25.72
250	" "	" "	22-81x14-39	41.25x26.22
265	" "	" "	20-83x16-33	47.93x23.71
1	" "	Cocos nucifera	28-81x22-41	50.40x30.23
3	" "	" "	30-91x20-43	59.05x26.67
17	" "	" "	24-103x18-43	58.14x30.93
16	" "	Dendrobium Maccarthiae	32-79x20-35	51.75x25.13
9	" "	Gossypium barbadense	22-89x16-39	52.07x25.73
14	" "	Hevea brasiliensis	28-77x18-35	50.27x24.55
272	" "	Mimusops sp.	22-57x16-39	41.75x29.89
235	" "	Piper betle	22-69x18-37	43.75x28.72
146	" "	Sabal causiarum	26-83x16-39	55.39x29.83
4	" "	Theobroma cacao	32-89x18-37	55.90x27.22
5	" "	" "	22-83x18-39	43.25x28.55
7	" "	" "	24-67x18-41	42.27x29.49
255	P. palmivora (atypical)	Cattleya sp.	22-65x18-43	43.08x31.06
180	" "	Citrus sp.	20-59x12-33	31.68x21.54
126	" "	Cocos nucifera	16-67x12-43	31.56x24.21
136	" "	" "	22-53x16-37	37.34x25.05
97	" "	Erythrina sp.	16-33x12-27	23.31x18.72
102	" "	Hevea brasiliensis	14-45x12-35	24.67x20.37
116	" "	" "	18-45x12-29	29.16x20.52
140	" "	" "	22-67x18-43	47.73x31.48
15	" "	Odontadenia speciosa	18-61x12-43	35.44x25.53
138	" "	Solanum melongena	26-83x16-43	45.49x29.23
18	" "	Theobroma cacao	16-39x14-29	25.95x20.82
22	" "	" "	20-43x14-33	30.30x24.58
26	" "	" "	16-49x14-41	29.56x25.30
36	" "	" "	18-49x14-33	32.12x17.64
44	" "	" "	20-47x12-39	30.53x18.00
100	" "	" "	14-55x12-31	25.05x18.55
121	" "	" "	26-63x18-45	47.26x33.56
130	" "	" "	18-67x12-43	44.99x33.38
141	" "	" "	16-37x12-27	25.99x19.05
254	" "	Vanda sp.	26-65x20-41	42.25x30.39
185	P. parasitica	Ananas Ananas	30-63x18-45	49.93x34.57
228	" "	Bryophyllum pinnatum	20-53x18-43	36.74x28.39
268	" "	" "	20-63x12-43	32.57x22.54
183	" "	Capsicum annuum	24-69x18-49	41.08x31.06
209	" "	" "	18-45x12-27	28.89x21.21
260	" "	Catharanthus roseus	22-57x16-39	36.74x27.56
2	" "	Cocos nucifera	30-109x18-41	59.68x29.86
8	" "	Gossypium barbadense	22-57x20-43	39.75x31.56
10	" "	" "	22-69x14-49	42.59x32.23
11	" "	" "	24-57x16-39	43.05x29.27
142	" "	Hibiscus sabdariffa	20-67x14-37	42.50x25.71
261	" "	" "	22-73x18-53	43.59x33.06
262	" "	" "	24-67x18-49	41.92x30.90

TABLE 3.—EXTREME AND AVERAGE DIMENSIONS OF 400 SPORANGIA OF 11 SPECIES OF PHYTOPHTHORA. MEASUREMENTS IN MICRA. (CONTINUED)

No.	Species	Host	Extremes	Average
211	" "	Lilium regale	22-63x18-43	40.92x28.72
212	" "	" "	24-71x20-59	49.10x37.74
270	" "	Lilium sp.	24-61x20-43	42.59x31.56
162	" "	Lycopersicon Lycopersicon	24-69x16-51	42.25x32.56
177	" "	" "	22-81x16-59	51.27x38.41
181	" "	" "	22-59x20-49	37.37x29.02
191	" "	" "	22-51x20-41	37.44x30.09
251	" "	" "	24-69x18-51	44.42x33.40
264	" "	Manihot sp.	22-53x18-37	34.54x25.38
143	" "	Musa textilis	18-47x12-31	27.05x18.87
259	" "	Pollia sp.	22-63x18-49	38.91x29.89
169	" "	Rheum Rhaponticum	18-43x12-29	28.06x17.70
204	" "	" "	24-73x20-49	41.91x31.22
139	" "	Solanum melongena	20-63x14-33	33.85x24.18
161	" "	" "	28-79x22-49	46.92x34.07
207	" "	Solanum tuberosum	22-39x14-29	30.89x22.04
145	" "	Theobroma cacao	18-63x14-37	33.14x22.79
263	" "	Vigna sp.	24-75x18-61	44.42x33.73
151	" "	Unknown	20-49x14-39	32.56x25.89
164	" "	"	20-59x16-42	38.41x29.39
171	" "	"	24-57x18-39	37.91x27.89
166	" "	"	22-59x16-49	37.24x28.89

Table 4 contains average dimensions for various species compiled from the measurements for individual cultures in Table 3.

TABLE 4.—AVERAGE DIMENSIONS OF SPORANGIA OF VARIOUS SPECIES COMPILED FROM TABLE 3

Species	Extremes (micra)	Average (micra)	Isolations examined
P. arecae	18-43x14-33	33.93x24.78	1
P. boehmeriae	28-69x20-51	51.77x40.08	1
P. cactorum	19-46x16-32	30.39x22.77	10
P. capsici	20-64x15-36	33.96x24.93	2
P. citrophthora	27-57x18-33	37.70x23.55	1
P. colocasiae	21-77x15-37	35.60x21.94	2
P. infestans	22-57x15-30	36.74 x21.96	2
P. meadii	23-72x18-39	40.41x28.39	2
P. nicotianae	18-61x14-39	35.07x25.22	1
P. palmivora (typ.)	26-79x18-39	48.80x28.13	22
P. palmivora (atyp.)	19-54x14-37	34.30x24.60	20
P. parasitica	22-63x17-41	39.64 x28.84	35

The average dimensions of sporangia of *P. cactorum*, *P. palmivora* and *P. parasitica* based on a number of isolations may be considered the norms for those species, but variations in individual cultures do not permit attaching much importance to them as taxonomic criteria.

Some cultures failed to sporulate freely on any of the media, and fewer than 400 sporangia were measured. Their dimensions are contained in Table 5. The sporangia were borne in lima bean, oatmeal or corn meal agar cultures.

TABLE 5.—MEASUREMENTS OF 25 TO 50 SPORANGIA OF SPECIES AND STRAINS WHICH FRUITED SPARINGLY. MEASUREMENTS IN MICRA.

No.	Species	Host	Extremes	Average
190	P. cactorum	Lilium sp.	21-39x16-32	32.2x24.0
243	" "	Paeonia sp.	21-30x18-30	28.0x22.7
149	" "	Pinus sp.	26-45x20-34	32.2x24.4
196	" "	Pyrus malus	26-35x15-29	28.9x20.4
267	P. citricola	Citrus sp.	21-37x23-27	32.3x25.6
154	P. citrophthora	" "	29-43x16-29	36.1x24.3
221	" "	" "	25-45x18-31	34.6x25.1
246	P. hibernalis	" "	28-41x15-23	34.4x17.9
241	P. hydrophila	Capsicum annuum	27-58x23-48	46.9x35.9
238	P. meadii	Hevea brasiliensis	25-59x20-31	40.1x25.4
232	P. nicotianae	Nicotiana tabacum	24-63x19-50	41.2x31.7
247	" "	" "	32-52x24-37	40.2x28.7
6	P. palmivora (atypical)	Theobroma cacao	26-65x21-39	44.8x28.2
269	P. parasitica	Catharanthus roseus	25-59x20-46	37.1x28.6
144	" "	Citrus sp.	29-37x20-29	34.1x24.0
178	" "	" "	37-74x30-54	62.1x45.7
258	" "	Grammatophyllum sp.	23-50x17-31	36.9x24.7
165	" "	Lilium sp.	28-65x21-43	41.4x29.6
186	" "	Lycopersicon Lycopersicon	31-65x23-44	45.9x33.1
187	" "	" "	27-55x19-40	39.6x28.6
217	" "	Nicotiana tabacum	27-56x20-43	41.2x29.4
175	" "	Rheum Rhaponticum	26-36x17-29	31.6x24.9
234	" "	Ricinus communis	28-66x19-50	50.1x39.7
182	" "	Solanum melongena	25-54x21-40	41.1x30.7
201	" "	" "	30-52x20-39	40.6x30.1
202	" "	" "	23-50x19-37	38.1x28.9
213	" "	" "	18-31x16-25	24.9x18.9
252	" "	" "	31-55x17-41	41.8x28.9
197	" "	Solanum tuberosum	22-55x17-41	35.2x25.2
203	" "	" "	22-48x19-35	33.4x24.5
167	" "	Unknown	27-60x21-40	46.9x32.7
199	" "	"	18-32x14-22	24.5x18.4
205	" "	"	41-80x29-55	59.6x43.6

A summary compiled from the averages for individual cultures listed in Table 5 is contained in Table 6.

TABLE 6.—AVERAGE DIMENSIONS OF SPORANGIA OF VARIOUS SPECIES AS COMPILED FROM TABLE 5

Species	Extremes (micra)	Average (micra)	Isolations examined
P. cactorum	23-40x17-31	30.3x22.9	4
P. citricola	31-37x23-27	34.3x25.6	1
P. citrophthora	27-44x17-30	35.3x24.7	2
P. hibernalis	28-41x15-23	34.4x17.9	1
P. hydrophila	27-58x23-48	46.9x35.9	1
P. meadii	25-59x20-31	40.1x25.4	1
P. nicotianae	28-57x21-44	40.7x30.2	2
P. palmivora (atyp.)	26-65x21-39	44.8x28.2	1
P. parasitica	27-54x20-39	40.3x29.5	20

It has been stated that a culture producing sporangia freely on one medium produces smaller sporangia on another less favorable to their production. However, the cultures which sporulate rather sparsely on all media produce sporangia very similar in size to those borne by profusely fruiting cultures. Compare the average sizes for *P. cactorum*, *P. citrophthora*, *P. meadii* and *P. parasitica* in Tables 4 and 6. It is

unfortunate that so few isolations of most species were available, but it is probably true that considerable variation in sporangium size occurs within each species.

Cultures that produced sporangia rarely or not at all on the solid substrata were tried in Petri's (164)* mineral solution to which sterile or non-sporangium-producing mycelium was transferred and examined after one week. Table 7 contains the measurements obtained.

TABLE 7.—AVERAGE DIMENSIONS OF 25 TO 50 SPORANGIA BORNE IN PETRI'S SOLUTION BY ISOLATIONS WHICH PRODUCED THEM RARELY OR NOT AT ALL ON THE SOLID MEDIA USED

No.	Species	Extremes (micra)	Average (micra)
149	P. cactorum	26-45x20-34	33.2x24.4
160	P. cactorum	22-50x17-38	35.6x28.2
198	P. cambivora	32-65x23-41	47.6x31.1
174	P. cinnamomi	31-62x21-30	43.6x25.9
242	P. cinnamomi	30-64x22-39	46.1x31.3
150	P. cryptogea	25-49x16-29	36.7x21.9
156	P. syringae	21-33x15-27	24.4x19.7
206	P. drechsleri	24-38x15-24	31.4x21.0

P. cambivora, *P. cinnamomi*, *P. cryptogea*, and *P. drechsleri* produce non-papillate sporangia in Petri's solution. The papilla which occurs in most species is a hyaline plug which ordinarily is more or less elevated above the surrounding sporangium wall, but in *P. cactorum* it is frequently inconspicuous, and in *P. syringae* it is usually not elevated and, frequently, even flattened. *P. cambivora*, *P. cinnamomi*, *P. cryptogea* and *P. drechsleri* produce sporangia which have no conspicuous hyaline plug and the oval contour of the apex is unbroken. It is usually easy to distinguish between these non-papillate sporangia and those of other species with inconspicuous ones, and no cultures have been seen in which the characteristic type could not be determined with certainty. Compare Figs. 1 and 2.

The above species which produce nonpapillate sporangia are also unique in the resumption of growth of the sporangiophores through the bases of evacuated sporangia. Renewed growth is followed by repeated sporangium development beyond or inside the old sporangium, or a resumption of mycelial growth by the sporangiophores which become branching hyphae.

No measurements of sporangia were recorded for the following isolations; No. 148 (*P. mexicana*), Nos. 173, 195, and 244 (*P. cinnamomi*, No. 176 (*P. erythroseptica*), and No. 227 (*P. richardiae*). *P. mexicana* produces a few papillate sporangia on potato dextrose agar. *P. erythroseptica* produces an occasional non-papillate, obpyriform sporangium in

*Petri's mineral solution: calcium nitrate, 0.4 g.; magnesium sulphate, 0.15 g.; potassium acid phosphate, 0.15 g.; potassium chloride, 0.06 g.; water, 1000 c.c.

M/100 potassium nitrate solution to which sterile mycelium is transferred, as recommended by Leonian and Geer (119).

The dimensions of sporangia, considered independently of other characters, cannot be accorded much importance, taxonomically. In connection with other characters, however, their morphology becomes of some value, especially in the species which produce non-papillate sporangia and show renewed elongation of sporangiophores through empty sporangia. These species may be grouped on this basis.

Chlamydospores

The extreme and average diameters of chlamydospores of isolations which produce them abundantly on at least one medium, are presented in Table 8.

Among the cultures of *P. cactorum* the average diameter varies from 19.04μ to 32.56μ; of *P. citrophthora*, from 27.55μ to 28.39μ; of *P. nicotianae*, from 21.38μ to 28.56μ; of typical cultures of *P. palmivora*, from 26.30μ to 37.57μ; of atypical cultures of *P. palmivora*, from 21.36μ to 40.28μ; and of *P. parasitica*, from 17.68μ to 39.60μ.

P. palmivora and *P. parasitica* usually produce larger chlamydospores than the other species mentioned, but the range for *P. parasitica* is wide enough to include the averages of all other species.

Combining the averages for individual strains to obtain species averages gives the figures in Table 9.

The chlamydospores of *P. cactorum* differ from those of most species. The walls are usually no thicker than those of the sporangia and they do not become much darker in color. The chlamydospores are very similar in appearance to unfertilized oogonia and it is possible, perhaps probable, that the bodies here considered chlamydospores are oogonia which failed to come into contact with antheridia, or failed to become fertilized from other causes. Occasionally these "chlamydospores" were observed with an attached antheridium. They germinate by germ tubes, as unfertilized oogonia have been observed to do. Unfertilized oogonia frequently become much larger than those in which the oospore develops.

Typical and atypical cultures of *P. palmivora* produce chlamydospores of about the same average diameters and larger than the averages for other species except *P. bochmeriae* of which only one isolation was examined.

P. cinnamomi produces vesicles resembling chlamydospores but distinguishable from true chlamydospores. They are irregular in size and shape, sometimes lobed or constricted, and are frequently in clusters or irregularly branching chains (Fig. 10). In old cultures the hyaline walls are often so thickened that the interior of the spore is nearly filled, the contents disappearing.

TABLE 8.—EXTREME AND AVERAGE DIAMETERS OF CHLAMYDOSPORES OF CULTURES PRODUCING ABUNDANTLY (400 MEASURED). MEASUREMENTS IN MICRA.

No.	Species	Extremes	Average	No.	Species	Extremes	Average
153	P. arecae	18-40	25.74	185	P. parasitica	22-62	39.60
266	P. boehmeriae	26-51	41.42	228	" "	16-63	36.07
192	P. cactorum	16-31	23.55	268	" "	20-57	36.91
194	" "	12-37	21.37	183	" "	18-43	25.72
179	" "	14-43	25.22	209	" "	14-35	23.21
184	" "	14-27	19.04	260	" "	14-29	19.53
189	" "	18-45	27.72	269	" "	14-49	26.55
193	" "	16-45	27.72	144	" "	16-41	26.17
168	" "	16-49	27.72	178	" "	16-49	30.89
172	" "	22-47	32.56	2	" "	16-45	22.46
200	" "	14-41	26.56	8	" "	16-39	24.48
210	" "	16-39	23.50	10	" "	18-51	29.00
190	" "	20-39	28.72	11	" "	18-61	34.02
*174	P. cinnamomi	20-49	32.40	258	" "	14-43	24.88
*244	" "	18-47	27.39	142	" "	14-39	23.58
154	P. citrophthora	20-39	28.39	261	" "	16-43	26.72
221	" "	14-49	28.06	262	" "	14-29	18.54
222	" "	16-43	27.55	165	" "	14-35	22.71
216	P. nicotianae	14-43	28.56	211	" "	14-55	28.06
232	" "	14-39	23.88	212	" "	14-41	24.55
247	" "	14-33	21.38	270	" "	14-37	24.88
271	P. palmivora (typ.)	20-50	37.57	132	" "	18-41	26.27
12	" "	20-47	34.90	162	" "	14-45	26.72
123	" "	22-49	37.37	177	" "	14-59	32.56
236	" "	18-43	31.40	181	" "	14-31	22.04
13	" "	16-49	31.63	186	" "	14-31	22.15
127	" "	16-41	26.30	187	" "	18-45	29.60
137	" "	22-41	31.03	191	" "	12-35	20.00
249	" "	16-45	29.23	251	" "	16-59	32.73
250	" "	16-49	31.56	264	" "	12-41	24.96
265	" "	14-43	29.56	143	" "	14-37	21.71
1	" "	22-49	32.96	217	" "	16-29	21.38
3	" "	16-49	34.21	259	" "	18-57	28.39
17	" "	16-51	31.02	159	" "	16-35	23.71
16	" "	18-55	36.69	169	" "	12-37	21.21
9	" "	16-45	30.56	175	" "	16-41	25.55
14	" "	18-53	31.49	204	" "	12-41	19.87
146	" "	16-49	33.85	234	" "	12-27	19.21
4	" "	22-55	34.22	139	" "	16-39	25.50
5	" "	18-47	29.90	161	" "	14-33	21.38
7	" "	18-51	31.96	182	" "	14-39	22.04
255	P. palmivora (atyp.)	18-43	31.90	201	" "	12-33	19.30
180	" "	14-39	24.22	202	" "	14-35	23.71
126	" "	18-53	36.57	213	" "	14-33	20.87
136	" "	20-49	35.58	252	" "	20-53	34.74
97	" "	14-29	21.36	197	" "	16-47	30.73
102	" "	12-37	22.19	203	" "	14-39	24.75
140	" "	18-49	36.41	207	" "	12-39	23.71
15	" "	18-43	28.79	145	" "	16-31	22.09
138	" "	20-47	35.70	263	" "	16-43	28.06
18	" "	14-37	23.38	151	" "	18-41	24.93
22	" "	14-29	22.20	164	" "	14-45	26.72
26	" "	20-51	32.60	166	" "	14-41	23.71
100	" "	20-53	30.23	167	" "	16-43	25.55
121	" "	24-59	39.41	171	" "	12-49	25.72
6	" "	16-55	40.28	199	" "	14-39	22.71
130	" "	20-39	30.63	205	" "	12-29	17.68
254	" "	20-45	32.56				

*Producing vesicles instead of true chlamydospores.

P. arecae, *P. citrophthora*, *P. nicotianae*, and *P. parasitica* have chlamydospores of similar average diameters and indistinguishable from each other or *P. palmivora*.

P. richardiae and *P. erythroseptica* produce, on mycelium transferred to M/100 potassium nitrate solution, vesicles resembling, slightly those of *P. cinnamomi*. They are produced in chains rather than clusters.

Some cultures do not develop chlamydospores profusely on any of the media used. Table 10 contains data regarding such cultures.

TABLE 9.—EXTREME AND AVERAGE DIAMETERS OF CHLAMYDOSPORES OF SPECIES COMPILED FROM THE MEASUREMENTS FROM INDIVIDUAL CULTURES IN TABLE 8

Species	Extremes (micra)	Average (micra)	Isolations examined
P. arecae	18-40	25.74	1
P. boehmeriae	26-51	41.42	1
P. cactorum	16-40	25.79	11
P. cinnamomi	19-48	29.89	2
P. citrophthora	17-44	28.00	3
P. nicotianae	14-38	26.91	3
P. palmivora (typ.)	18-48	32.37	20
P. palmivora (atyp.)	18-45	31.24	17
P. parasitica	15-42	25.43	57

TABLE 10.—EXTREME AND AVERAGE DIAMETERS OF 25 TO 50 CHLAMYDOSPORES OF ISOLATIONS PRODUCING THEM SPARSELY

No.	Species	Extremes (micra)	Average (micra)
243	P. cactorum	23-43	31.6
*173	P. cinnamomi	15-42	26.1
*195	P. cinnamomi	18-42	29.5
*242	P. cinnamomi	21-44	30.7
239	P. colocasiae	22-38	30.1
*150	P. cryptogea	17-29	23.2
223	P. meadii	25-36	29.4
238	P. meadii	24-30	27.8
257	P. meadii	16-35	24.7
36	P. palmivora (atyp.)	27-40	34.7
44	P. palmivora (atyp.)		28.4
141	P. palmivora (atyp.)	13-24	16.0

*Measurements of vesicles resembling chlamydospores.

The diameter of chalmydospores produced sparsely are very similar to those of spores formed in profusion. The following cultures produced them rarely or never. No. 152 (*P. colocasiae*); Nos. 147 and 253 (*P. capsici*); No. 241 (*P. hydrophila*); No. 198 (*P. cambivora*) (No. 208 (*P. cambivora*) produces hyphal swellings which can hardly be considered chlamydospores); No. 246 (*P. hibernalis*); No. 267 (*P. citricola*); Nos. 116, 272 and 235 (*P. palmivora*); No. 148 (*P. mexicana*); Nos. 149, 196, and 160 (*P. cactorum*); No. 176 (*P. erythroseptica*); Nos. 245 and 248 (*P. infestans*); Nos. 156 and 230 (*P. syringae*); and No. 227 (*P. richardiae*).

P. palmivora usually produced very numerous chlamydospores, yet 3 cultures produced very few. *P. cactorum* cultures differ widely in chlamydospore-forming tendencies. Further discussion of the data is unnecessary; the abscence of chlamydospores in *P. capsici* and *P. hydrophila* is helpful in distinguishing them from *P. parasitica*; the profuse development of vesicles serves to distinguish *P. cinnamomi*. Like data for sporangia, data for chlamydospores may be useful in connection with other taxonomic standards.

Oogonia, Antheridia and Oospores

Measurements of oogonia and oospores were made whenever they were observed. The range of variation is smaller than for sporangia and chlamydospores and only 25 to 50 were measured. Trials indicated that the average diameter of these small numbers deviated but slightly from averages of 200 measurements. Antheridia were observed carefully to determine whether they were amphigynous or paragynous. Antheridia are considered amphigynous when they are apparently penetrated by the oogonial stalk, becoming a permanent "collar" enclosing it (Figs. 6, 7, 8 and 9). Paragynous antheridia (Figs. 4, 5) may simulate amphigynous ones by their close contact with the stalk, and occasional truly amphigynous antheridia *may* occur in cultures in which the paragynous type predominates. However, paragynous antheridia seldom or never appear in cultures where the prevailing type is amphigynous. Among all cultures examined not one has been observed in which a few minutes examination of the antheridia failed to determine the predominant type.

The observations are recorded in Table 11. Isolations which failed to produce oogonia on any medium used are omitted.

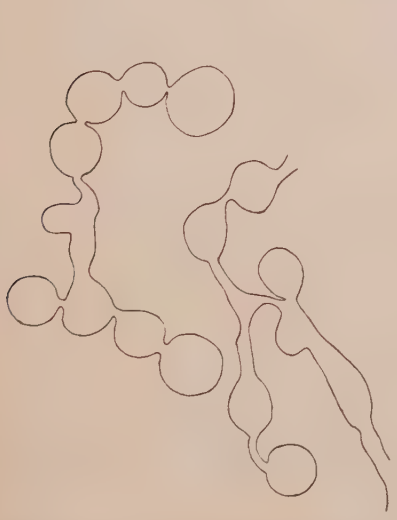

Fig. 11.—*P. cryptogea* (No. 150). Hyphae with nodules or vesicles occasionally observed in a culture on oatmeal agar 4 months old. (x375).

Fig. 12.—*P. capsici* (No. 147). Swollen hyphae and vesicles occasionally found in cultures on oat meal agar 4 months old. (x350).

All isolations of *P. cactorum*, *P. citricola*, *P. hibernalis*, and *P. syringae* produce oogonia with paragynous antheridia promptly and abundantly. No other species has predominantly paragynous antheridia.

TABLE 11. OCCURRENCE OF OOGONIA AND OOSPORES, PREDOMINATING TYPE OF ANTHERIDIUM, AND EXTREME AND AVERAGE DIAMETERS OF OOGONIA AND OOSPORES ON VARIOUS MEDIA. MEASUREMENTS IN MICRA. 1-OOGONIA; 2-OOSPORES

No.	Species	Steamed corn meal 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.	Antheridium type and average diameter for all media
266	P. boehmeriae	abundant; amphigynous; 1-20.9-30.9; ave. 26.1. 2-17.5-27.6; ave. 24.2.	abundant; amphigynous; 1-23.4-30.1; ave. 27.5. 2-20-25.1; ave. 23.	abundant; amphigynous; 1-20.9-29.2; ave. 25.2. 2-15.7-25.9; ave. 22.	fairly abundant; amphigynous; 1-21.7-31.7; ave. 28. 2-20.9-27.6; ave. 25.1.	abundant; amphigynous; 1-21.7-30.1; ave. 25.7. 2-19.2-24.2; ave. 22.4.	amphigynous; 1—ave. 26.5. 2—ave. 23.3.
192	P. cactorum	very few; paragynous; 1-24-32.6; ave. 27.4. 2—ave. 25.2.	abundant; paragynous; 1-26.7-36.7; ave. 31.4. 2-23.4-30.1; ave. 26.2.	abundant; paragynous; 1-26.7-30.1; ave. 28.1. 2-21.7-25.9; ave. 24.5.	abundant; paragynous;	abundant; paragynous; 1-26.7-37.6; ave. 30.7. 2-22.5-30.9; ave. 26.7.	paragynous; 1—ave. 29.4. 2—ave. 25.6.
194	P. cactorum	abundant; paragynous; 1-21.7-30.9; ave. 28.2. 2-20-28.4; ave. 25.7.	abundant; paragynous; 1-25.9-34.2; ave. 29.2. 2-22.5-29.2; ave. 25.	abundant; paragynous; 1-21.7-31.7; ave. 25.1. 2-20.9-27.6; ave. 22.7.	abundant; paragynous; 1-24.2-30.9; ave. 26.4. 2-21.7-26.7; ave. 24.	rare; paragynous;	paragynous; 1—ave. 26.8. 2—ave. 24.2.
179	P. cactorum	abundant; paragynous; 1-25-28.3; ave. 26.2. 2-22.5-25.9; ave. 24.2.	abundant; paragynous; 1-22.5-33.4; ave. 28.2. 2-19.2-29.2; ave. 24.5.	abundant; paragynous; 1-24.2-34.2; ave. 28.1. 2-21.7-30.1; ave. 25.6.	abundant; paragynous; 1-25.9-37.6; ave. 28.9. 2-20-30.9; ave. 25.7.	abundant; paragynous; 1-25.1-37.6; ave. 30.6. 2-21.7-33.4; ave. 26.4.	paragynous; 1—ave. 28.4. 2—ave. 25.3.
184	P. cactorum	abundant; paragynous; 1-21.6-30.6; ave. 26.8. 2-19.7-27.9; ave. 24.9.	fairly abundant; paragynous; 1-23.4-36.7; ave. 28.6. 2-20.9-32.6; ave. 25.7.	abundant; paragynous; 1-25.1-31.7; ave. 28.2. 2-23.4-26.7; ave. 25.4.	abundant; paragynous;	abundant; paragynous; 1-27.6-33.4; ave. 30.2. 2-25.1-31.7; ave. 27.7.	paragynous; 1—ave. 28.4. 2—ave. 25.9.
189	P. cactorum	abundant; paragynous; 1-25-33.4; ave. 27.5. 2-23.4-31.7; ave. 25.7.	very few; paragynous; 1-25.7-34.2; ave. 28.9 2-23.4-31.7; ave. 25.2.	abundant; paragynous; 1-20-31.7; ave. 25.9. 2-16.7-29.2; ave. 23.9.	abundant; paragynous;	abundant; paragynous; 1-23.4-33.4; ave. 28.9. 2-21.7-30.2; ave. 25.9.	paragynous; 1—ave. 27.8. 2—ave. 25.2.
193	P. cactorum	abundant; paragynous; 1-23.4-32.5; ave. 26.7. 2-21.7-27.5; ave. 24.3.	abundant; paragynous; 1-26.7-37.6; ave. 31.6. 2-23.4-30.1; ave. 26.7.	abundant; paragynous; 1-24.2-32.6; ave. 27.7. 2-23.4-30.1; ave. 25.9.	abundant; paragynous;	abundant; paragynous; 1-21.7-33.4; ave. 26.6. 2-19.2-30.1; ave. 24.	paragynous; 1—ave. 28.1. 2—ave. 25.2.

168	P. cactorum	few; paragynous;	abundant; paragynous; 1-21.7-32.6; ave. 27.2. 2-19.2-28.4; ave. 23.5.	abundant; paragynous; 1-21.7-30.9; ave. 26.4. 2-20-27.4; ave. 24.1.	abundant; paragynous;	abundant; paragynous; 1-20.9-30.9; ave. 27.4; 2-20-28.4; ave. 25.1.	paragynous; 1—ave. 27. 2—ave. 24.2.
172	P. cactorum	abundant; paragynous; 1-22.5-31.8; ave. 26.9.	few; paragynous; 1-25.9-32.6; ave. 28.5. 2-20.9-27.6; ave. 24.	fairly abundant; paragynous; 1-25-31.7; ave. 29.9. 2-22.5-29.2; ave. 26.2.	abundant; paragynous; 1-23.4-33.4; ave. 28.2. 2-20-29.2; ave. 23.2.	abundant; paragynous; 1-20.9-30.1; ave. 26.7. 2-19.2-27.6; ave. 24.2.	paragynous; 1—ave. 28. 2—ave. 24.4.
200	P. cactorum	abundant; paragynous; 1-25-33.1; ave. 27.9. 2-22.5-30.9; ave. 26.1.	very few; paragynous; 1-20.9-25.1; ave. 23.5. 2-18.4-23.4; ave. 21.4.	abundant; paragynous; 1-25.1-30.9; ave. 28.6. 2-23.4-29.2; ave. 26.5.	abundant; paragynous; 1-22.5-29.2; ave. 25.3. 2-20-26.7; ave. 23.4.	abundant; paragynous; 1-17.5-34.2; ave. 29.1. 2-15.9-30.9; ave. 25.2.	paragynous; 1—ave. 26.9. 2—ave. 24.5.
210	P. cactorum	abundant; paragynous; 1-23.3-32.6; ave. 27.7. 2-22.5-30; ave. 25.9.	fairly abundant; paragynous; 1-23.4-38.4; ave. 30.4. 2-20-32.6; ave. 26.1.	abundant; paragynous; 1-24.2-31.7; ave. 28.4. 2-22.5-27.6; ave. 25.7.	abundant; paragynous; 1-18.4-31.7. ave. 27.9. 2-17.5-28.4; ave. 24.7.	abundant; paragynous; 1-25.1-31.7; ave. 26.8. 2-22.5-28.4; ave. 24.2.	paragynous; 1—ave. 28.2. 2—ave. 25.3.
190	P. cactorum	abundant; paragynous; 1-23.4-36.7; ave. 27.4. 2-21.8-33.4; ave. 25.9.	abundant; paragynous; 1-27.6-36.7; ave. 30.7. 2-23.4-30.9; ave. 26.6.	abundant; paragynous; 1-22.5-30.1; ave. 27.2. 2-20.9-28.4; ave. 24.7.	abundant; paragynous; 1-23.4-30.1; ave. 26.6. 2-20-26.7; ave. 23.7.	abundant; paragynous; 1-25.9-31.7; ave. 27.9. 2-24.2-28.4; ave. 26.1.	paragynous; 1—ave. 28. 2—ave. 25.4.
243	P. cactorum	few; paragynous; 1-24.2-28.4; ave. 26.6. 2-23.4-25.9; ave. 24.	abundant; paragynous; 1-23.4-31.7; ave. 28.2. 2-18.4-28.4; ave. 24.6.	abundant; paragynous; 1-22.5-28.4; ave. 25.2. 2-20-26.7; ave. 23.	abundant; paragynous; 1-23.4-32.6; ave. 27.6. 2-22.5-30.9; ave. 25.5.	abundant; paragynous; 1-22.5-31.7; ave. 27.2. 2-20-29.2; ave. 25.2.	paragynous; 1—ave. 27. 2—ave. 24.5.
149	P. cactorum	very few; paragynous; 1—ave. 28.9. 2—ave. 26.	abundant; paragynous; 1-21.7-35.1; ave. 28.9. 2-17.5-31.7; ave. 26.	abundant; paragynous; 1-25.1-33.4; ave. 30.1. 2-23.4-30.1; ave. 27.7.	abundant; paragynous; 1-24.2-28.4; ave. 26.7. 2-20-26.7; ave. 24.	abundant; paragynous; 1-19.2-36.7; ave. 28.9. 2-17.5-34.2; ave. 25.6.	paragynous; 1—ave. 28.7. 2—ave. 25.5.
160	P. cactorum	few; paragynous;	abundant; paragynous; 1-20.9-33.4; ave. 29.9. 2-16.7-30.9; ave. 26.6.	abundant; paragynous; 1-21.7-31.7; ave. 27.7. 2-20-30.1; ave. 25.7.	abundant; paragynous;	abundant; paragynous; 1-25.9-34.2; ave. 29.4. 2-24.2-31.7; ave. 27.2.	paragynous; 1—ave. 29. 2—ave. 26.5.

TABLE 11.—OCCURRENCE OF OOGONIA AND OOSPORES, PREDOMINATING TYPE OF ANTHERIDIUM, AND EXTREME AND AVERAGE DIAMETERS OF OOGONIA AND OOSPORES ON VARIOUS MEDIA. MEASUREMENTS IN MICRA. 1-OOGONIA; 2-OOSPORES (CONTINUED)

No.	Species	Steamed corn meal 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.	Antheridium type and average diameter for all media
196	P. cactorum	fairly abundant; paragynous; 1-23.4-32.5; ave. 26.6.	fairly abundant; paragynous; 1-27.6-33.4; ave. 30.1. 2-23.4-30.1; ave. 26.2.	abundant; paragynous; 1-22.5-30.1; ave. 27.2. 2-21.7-26.7; ave. 24.9.	abundant; paragynous; 1-21.7-28.4; ave. 25.2. 2-20-24.2; ave. 23.	abundant; paragynous; 1-21.7-31.7; ave. 26.9. 2-20-29.2; ave. 24.9.	paragynous; 1—ave. 27.2. 2—ave. 24.7.
147	P. capsici	none.	rare; amphigynous; *1-27.6-32.6; ave. 28.4. *2-24.2-29.2; ave. 25.6.	rare; amphigynous; *1-23.4-33.4; ave. 28.1. *2-20.9-26.7; ave. 24.8.	none.	very few; amphigynous; *1—ave. 27.6. *2—ave. 24.2.	amphigynous; 1—ave. 28.7. 2—ave. 24.9.
253	P. capsici	none.	rare; amphigynous;	fairly abundant; amphigynous; 1-23.4-34.2; ave. 30.1. 2-20.9-30.1; ave. 26.1.	none.	abundant; amphigynous; 1-17.5-31.7; ave. 26.4. 2-15-28.4; ave. 23.5.	amphigynous; 1—ave. 28.2. 2—ave. 24.8.
267	P. citricola	fairly abundant; paragynous; 1-21.7-31.7; ave. 26.1. 2-19.2-28.4; ave. 23.4.	abundant; paragynous; 1-22.5-34.2; ave. 27. 2-20.9-30.1; ave. 24.2.	abundant; paragynous; 1-20-30.1; ave. 26.7. 2-18.4-27.6; ave. 24.5.	abundant; paragynous; 1-20-36.7; ave. 27.1. 2-17.5-27.6; ave. 23.7.	abundant; paragynous; 1-22.5-32.6; ave. 27.9. 2-19.2-30.1; ave. 25.3.	paragynous; 1—ave. 27. 2—ave. 24.2.
152	P. colocasiae	none.	none.	few; amphigynous; 1-26.7-37.4; ave. 34.4. 2-22.5-32.6; ave. 28.9.	none.	abundant; amphigynous; 1-18.4-33.4; ave. 23.9. 2-16.7-28.4; ave. 21.	amphigynous; 1—ave. 29.1. 2—ave. 25.
239	P. colocasiae	none.	rare; amphigynous; *1-24.2-32.6; ave. 28.7. *2-20-27.6; ave. 23.	very few; amphigynous; 1-23.4-30.9; ave. 25.9. 2-21.7-25.1; ave. 23.	very few; amphigynous; *1-25.1-34.2; ave. 30.4. *2-20.9-30.1; ave. 26.2.	few; amphigynous; 1-20-41.8; ave. 32.1. 2-17.5-34.2; ave. 26.7.	amphigynous; 1—ave. 29.3. 2—ave. 24.7.
150	P. cryptogea	none.	none.	none.	none.	none.	†amphigynous; 1—ave. 25.8. 2—ave. 22.8.

176	P. erythroseptica	none.	none.	none.	none.	abundant; amphigynous; 1-31.7-37.6; ave. 34.1. 2-26.7-33.4; ave. 30.2	†amphigynous; 1—ave. 36.3. 2—ave. 31.4.
**246	P. hibernalis	fairly abundant; paragynous; 1-20.9-31.7; ave. 27.7. 2-18.4-28.4; ave. 24.7.	fairly abundant; paragynous; 1-20.9-37.6; ave. 30.9. 2-16.7-32.6; ave. 27.9.	abundant; paragynous; 1-25.9-30.1; ave. 27.2. 2-21.7-28.4; ave. 25.2	abundant; paragynous; 1-21.7-35.9; ave. 30.6. 2-20-32.6; ave. 28.1.	abundant; paragynous; 1-20.9-29.2; ave. 25.4. 2-17.5-27.6; ave. 22.9.	paragynous; 1—ave. 28.4. 2—ave. 25.7.
241	P. hydrophila	none.	few; amphigynous; 1-27.6-32.6; ave. 29.9. 2-19.2-24.2; ave. 22.7.	none.	none.	abundant; amphigynous; 1-25.1-31.7; ave. 28.6. 2-20.9-30.1; ave. 25.5.	†amphigynous; 1—ave. 29.1. 2—ave. 24.4.
**248	P. infestans	none.	few; amphigynous; 1-23.4-29.2; ave. 26.4. 2-16.7-22.5; ave. 20.	none.	none.	rare; amphigynous;	†amphigynous; 1—ave. 27.9. 2—ave. 23.6.
148	P. mexicana	none.	fairly abundant; amphigynous; 1-24.2-33.4; ave. 29.6. 2-20-26.7; ave. 23.7.	none.	none.	very few; amphigynous; 1-27.5-34.2; ave. 31.9. 2-24.2-30.1 ave. 27.2.	amphigynous; 1—ave. 30.7. 2—ave. 25.4.
216	P. nicotianae	none.	none.	none.	none.	very few; amphigynous; 1-24.1-32.6; ave. 29.1. 2-19.6-27.1; ave. 25.2.	*amphigynous; 1—ave. 29.1. 2—ave. 25.2.
232	P. nicotianae	none.	none.	none.	none.	rare; amphigynous; *1-23.7-33.4; ave. 28.7. *2-20.7-29.3; ave. 24.9.	*amphigynous; 1—ave. 28.7. 2—ave. 24.9.
247	P. nicotianae	none.	few; amphigynous; 1-20.9-29.2; ave. 24.7. 2-16.7-23.4; ave. 20.2.	none.	none.	none.	†amphigynous; 1—ave. 25.6. 2—ave. 21.4.

TABLE 11.—OCCURRENCE OF OOGONIA AND OOSPORES, PREDOMINATING TYPE OF ANTHERIDIUM, AND EXTREME AND AVERAGE DIAMETERS OF OOGONIA AND OOSPORES ON VARIOUS MEDIA. MEASUREMENTS IN MICRA. 1-OOGONIA; 2-OOSPORES (CONTINUED)

No.	Species	Steamed corn meal 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.	Antheridium type and average diameter for all media
183	P. parasitica	few; amphigynous; 1-20.8-25; ave. 22.2. 2-16-20.8; ave. 16.9.	none.	none.	none.	none.	amphigynous; 1—ave. 22.2. 2—ave. 16.9.
209	P. parasitica	few; amphigynous; 1-16.7-25.9; ave. 21.5. 2-13.4-21.7; ave. 18.2.	none.	none.	none.	none.	amphigynous; 1—ave. 21.5. 2—ave. 18.2.
260	P. parasitica	none.	fairly abundant; amphigynous; 1-16.7-27.6; ave. 24.4. 2-15-25.1; ave. 21.	none.	none.	few; amphigynous; 1-26.7-30.9; ave. 29. 2-23.4-27.6; ave. 25.7.	†amphigynous; 1—ave. 27.2. 2—ave. 23.5.
269	P. parasitica	none.	abundant; amphigynous; 1-24.2-30.1; ave. 27.1. 2-21.7-26.7; ave. 23.7.	few; amphigynous; 1-21.7-32.6; ave. 27.6. 2-20-28.4; ave. 24.5.		fairly abundant; amphigynous; 1-20-30.9; ave. 25.4. 2-16.7-26.7; ave. 22.	amphigynous; 1—ave. 26.7. 2—ave. 23.4.
144	P. parasitica	none.	none.	none.	none.	rare; amphigynous; *1-24.2-34.2; ave. 31.1. *2-20.9-30.1; ave. 25.4.	*amphigynous; 1—ave. 31.1. 2—ave. 25.4.
178	P. parasitica	none.	none.	none.	none.	few; amphigynous; 1-21.7-28.4; ave. 26.2. 2-15.8-23.4; ave. 21.2.	amphigynous; 1—ave. 26.2. 2—ave. 21.2.
2	P. parasitica	none.	rare; amphigynous; *1—ave. 24.2. *2-ave. 21.71	none.	none.	few; amphigynous; *1-22.1-26.4; ave. 24.2. *2-19.7-23.7; ave. 21.7.	*amphigynous; 1—ave. 24.2. 2—ave. 21.7.

10	P. parasitica	none.	very few; amphigynous; 1-21.7-30.1; ave. 25.4. 2-17.5-25.9; ave. 21.7.	none.	none.	fairly abundant; amphigynous; 1-20.9-31.7; ave. 26. 2-19.2-29.2; ave. 23.1.	amphigynous; 1—ave. 25.7. 2—ave. 22.4.
11	P. parasitica	none.	none.	none.	none.		††amphigynous; 1—ave. 24.4.
261	P. parasitica	none.	abundant; amphigynous; 1-20.9-25.9; ave. 23.5. 2-15-20.9; ave. 18.7.	none.	none.	none.	amphigynous; 1—ave. 23.5. 2—ave. 18.7.
165	P. parasitica	none.	none.	none.	none.	abundant; amphigynous; 1-15-25.9; ave. 21.4. 2-13.4-22.5; ave. 19.	†amphigynous; 1—ave. 22.5. 2—ave. 19.
211	P. parasitica	none.	fairly abundant; amphigynous; 1-25.1-30.1; ave. 26.5. 2-19.2-24.2; ave. 21.	none.	few; amphigynous; 1-21.7-28.4; ave. 25.4. 2-20.9-25.9; ave. 22.4.	fairly abundant; amphigynous; 1-25.9-31.7; ave. 28.2. 2-22.5-28.4; ave. 24.2.	amphigynous 1—ave. 26.7. 2—ave. 22.5.
212	P. parasitica	none.	few; amphigynous; 1-27.6-34.2. ave. 29.6. 2-23.4-30.1; ave. 25.2.	none.	none.	abundant; amphigynous; 1-21.7-29.2; ave. 25.7. 2-17.5-26.7; ave. 22.4.	amphigynous; 1—ave. 27.7. 2—ave. 24.
270	P. parasitica	none.	rare; amphigynous; *1-22.5-28.4; ave. 25.8. *2-18.4-22.5; ave. 20.6.	none.		none.	*amphigynous; 1—ave. 25.8. 2—ave. 20.6.
132	P. parasitica	rare; amphigynous.	abundant; amphigynous; 1-22.5-30.1; ave. 26.7 2-20-26.7; ave. 23.2.	none.	abundant; amphigynous; 1-23.4-35; ave. 28. 2-19.2-30. ave. 23.4.	very few; amphigynous; *1-28.4-35.1; ave. 31.1. *2-25.1-30.1; ave. 27.1.	*amphigynous; 1—ave. 28.5. 2—ave. 24.9.

TABLE 11.—OCCURRENCE OF OOGONIA AND OOSPORES, PREDOMINATING TYPE OF ANTHERIDIUM, AND EXTREME AND AVERAGE DIAMETERS OF OOGONIA AND OOSPORES ON VARIOUS MEDIA. MEASUREMENTS IN MICRA. 1-OOGONIA; 2-OOSPORES (CONTINUED

No.	Species	Steamed corn meal 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.	Antheridium type and average diameter for all media
177	P. parasitica	none.	none.	fairly abundant; amphigynous; 1-21.7-29.2; ave. 24.7. 2-18.4-23.4; ave. 21.2.	rare; amphigynous.	none.	amphigynous; 1—ave. 24.7. 2—ave. 21.2.
181	P. parasitica	few; amphigynous; 1-22.5-25.9; ave. 24.4. 2-19.2-22.5; ave. 20.7.	none.	none.	none.	rare; amphigynous.	†amphigynous; 1—ave. 26.6. 2—ave. 22.8.
186	P. parasitica	none.	rare; amphigynous; *1-17.5-22.5; ave. 20.4. *2- ave. 18.6.	none.	none.	none.	*amphigynous; 1—ave. 20.4. 2—ave. 18.6.
251	P. parasitica	none.	none.	none.	none.	none.	†amphigynous; 1—ave. 25.5. 2—ave. 22.7.
143	P. parasitica	none.	rare; amphigynous.	none.	abundant; amphigynous; 1-25.1-31.8; ave. 27.1. 2-19.2-25.9; ave. 22.6.	rare; amphigynous; *1-30.1-35.1; ave. 32.7. *2-24.2-28.4; ave. 27.	amphigynous; 1—ave. 28.1. 2—ave. 23.6.
259	P. parasitica	none.	fairly abundant; amphigynous; 1-19.2-30.9 ave. 25.6. 2-10.9-25.1; ave. 20.7	none.	none.	few; amphigynous; 1-26.7-35.1; ave. 30.1. 2-23.4-29.2; ave. 26.7.	amphigynous; 1—ave. 27.8. 2—ave. 23.7.
159	P. parasitica	none	none.	very few; amphigynous	none.	none	†amphigynous; 1—ave. 30.4. 2—ave. 27.1.

175	P. parasitica	none.	none.	none.	none.	very few; amphigynou 1-20.9-40.1; ave. 29.1. 2-18.4-35.1; ave. 25.1.	†amphigynous; 1—ave. 27.5. 2—ave. 24.4.
204	P. parasitica	none.	none.	none.	none.	rare; amphigynous; *1-28.4-36.7; ave. 31.4. *2-22.7-30.1; ave. 27.7.	*amphigynous; 1—ave. 31.4. 2—ave. 27.7.
139	P. parasitica	none.	abundant; amphigynous; 1-24.2-31.7; ave. 27.2. 2-20-26.7 ave. 22.7.	none.	few; amphigynous; *1-29.2-31.7; ave. 30.4. *2-25.9-26.7; ave. 26.2.	fairly abundant; amphigynous; 1-25.9-35.1; ave. 29.4. 2-25.4-29.2; ave. 25.4.	amphigynous; 1—ave. 28.3. 2—ave. 24.
161	P. parasitica	none.	none.	none.	none.	very few; amphigynous; 1-22.5-37.6; ave. 27.9. 2-19.2-33.4; ave. 24.7.	amphigynous; 1—ave. 27.9. 2—ave. 24.7.
182	P. parasitica	abundant; amphigynous; 1-19.4-25.1; ave. 21.5. 2-15.9-21.7; ave. 18.9.	none.	none.	none.	none.	amphigynous; 1—ave. 21.5. 2—ave. 18.9.
201	P. parasitica	none.	abundant; amphigynous; 1-21.7-31.7; ave. 28.7. 2-19.2-25.9; ave. 23.4.	none.	very few; amphigynous; *1-28.4-33.4; ave. 30.4. *2-23.4-30.1; ave. 26.1.	abundant; amphigynous; 1-20-31.7; ave. 27.7. 2-15.9-30.1; ave. 24.7.	†amphigynous; 1—ave. 29. 2—ave. 25.6.
202	P. parasitica	none.	rare; amphigynous; *1-18.4-21.7; ave. 20. *2-14.2-18.4; ave. 16.5.	none.	rare; amphigynous;	very few; amphigynous; 1-21.7-31.7; ave. 27. 2-16.7-24.2; ave. 21.9.	amphigynous; 1—ave. 26.8. 2—ave. 21.7.
213	P. parasitica	none.	abundant; amphigynous; 1-20.9-30.1; ave. 26.4. 2-15.9-25.9; ave. 21.7.	fairly abundant; amphigynous; 1-25.1-35.9; ave. 29.1. 2-17.5-30.1; ave. 24.9.	rare; amphigynous;	none.	†amphigynous; 1—ave. 28.3. 2—ave. 24.4.

TABLE 11.—OCCURRENCE OF OOGONIA AND OOSPORES, PREDOMINATING TYPE OF ANTHERIDIUM, AND EXTREME AND AVERAGE DIAMETERS OF OOGONIA AND OOSPORES ON VARIOUS MEDIA. MEASUREMENTS IN MICRA. 1-OOGONIA; 2-OOSPORES (CONTINUED)

No.	Species	Steamed corn meal 2 wks.	Lima bean agar 4 mos.	Oatmeal agar 2 wks.	Corn meal agar 6 mos.	Oatmeal agar 4 mos.	Antheridium type and average diameter for all media
207	P. parasitica	none.	very few; amphigynous; *1-26.7-27.6; ave. 27.2. *2-21.7-22.5; ave. 22.2.	none.	rare; amphigynous *1-24.2-25.9; ave. 25.1. *2-21.7-24.2; ave. 22.9.	fairly abundant; amphigynous; 1-21.7-31.7; ave. 27.4. 2-18.4-27.6; ave. 24.	amphigynous; 1—ave. 27.2. 2—ave. 23.7.
145	P. parasitica	none.	none.	none.	none.	few; amphigynous; *1-25-30.1; ave. 26.9. *2-18.4-23.4; ave. 21.5.	*amphigynous; 1—ave. 26.9. 2—ave. 21.5.
263	P. parasitica	none.	abundant; amphigynous; 1-18.4-25.1; ave. 22.6. 2-15-20.9; ave. 18.9.	very few; amphigynous; 1-23.4-26.7; ave. 24.7. 2-20.9-22.5; ave. 21.4.	none.	few; amphigynous; 1-20-30.1; ave. 25.7. 2-16.7-25.1; ave. 22.	amphigynous; 1—ave. 24.3. 2—ave. 20.8.
164	P. parasitica	none.	none.	none.	rare; amphigynous;	none.	*†amphigynous; 1—ave. 27.6. 2—ave. 25.3.
199	P. parasitica	none.	none.	none.	none.	very few; amphigynous; *1-27.6-32.6; ave. 29.9. *2-25.1-30.9; ave. 27.7.	*amphigynous; 1—ave. 29.9. 2—ave. 27.7.
227	P. richardiae	none.	none.	none.	none.	none.	†amphigynous; 1—ave. 28.9. 2—ave. 25.4.

**156	P. syringae	fairly abundant; paragynous; 1-24.2-30.1; ave. 27.1. 2-20.9-26.7; ave. 24.2.	few; paragynous; 1-25.1-32.6; ave. 29.6. 2-22.5-27.6; ave. 25.2.	abundant; paragynous; 1-23.4-30.9; ave. 27.4. 2-20-26.7; ave. 24.	abundant; paragynous; 1-19.2-35.1; ave. 27.7. 2-15.9-31.7; ave. 25.1.		paragynous; 1—ave. 27.9. 2—ave. 24.6.
**230	P. syringae	fairly abundant; paragynous; 1-20.9-32.6; ave. 28.2. 2-18.4-28.4; ave. 24.9.	fairly abundant; paragynous; 1-26.7-31.7; ave. 28.6. 2-20.9-27.6; ave. 24.5.	abundant; paragynous; 1-25-35.9; ave. 30.1. 2-21.7-30.9; ave. 26.9.	abundant; paragynous; 1-25.9-33.4; ave. 29.1. 2-23.4-30.1; ave. 26.4.		paragynous; 1—ave. 29. 2—ave. 25.5.
206	P. drechsleri	none.	none.	none.	none.	few; amphigynous; *1-26.7-53.4; ave. 39.1. *2-20-45.1; ave. 32.1.	†amphigynous; 1—ave. 31.3. 2—ave. 25.6.

*Fewer than 25 measured; **Kept at about 10 degrees C.
†Data partially or entirely from overwintered oatmeal agar cultures. ††Data from 11 weeks old steamed bean pod cultures.

Of the species producing oogonia with predominantly amphigynous antheridia *P. boehmeriae* may be distinguished by its early and abundant production of oogonia on steamed corn meal, lima bean, oatmeal and corn meal agars. *P. colocasiae* and a few isolations of *P. parasitica* produce them fairly promptly on oatmeal agar, but not on steamed corn meal. A few isolations of the latter produced them on steamed corn meal, but not on oatmeal agar. *P. boehmeriae* may be distinguished from both species by its profuse production of oogonia on both media.

P. capsici, *P. colocasiae*, *P. cryptogea*, (Fig. 7), *P. erythroseptica*, *P. hydrophila*, *P. infestans*, *P. mexicana*, (Fig. 6), *P. nicotianae*, *P. parasitica* (Figs. 8 and 9), *P. richardiae* and *P. drechsleri* (Fig. 3) produced oogonia with amphigynous antheridia. *P. colocasiae* and a few isolations of *P. parasitica* produced them on oatmeal agar fairly readily. Other isolations of *P. parasitica* produced oogonia rarely and in some they were absent on the media used. Nos. 11 and 251 produced them only in cultures which had overwintered out-of-doors at Columbia, Mo.

One isolation of *P. infestans* (No. 248) formed oogonia in small numbers regularly in old cultures while another (No. 245) failed to produce them. Single isolations of *P. cryptogea* and *P. richardiae* produced sexual spores only in overwintered cultures.

The following species produced no oogonia in the cultures examined; *P. arecae*, *P. cambivora*, *P. citrophthora*, *P. meadii*, *P. palmivora*, 21 of 57 isolations of *P. parasitica*, and 1 of 2 isolations of P. *infestans*.

It is apparent that the presence or absence of sexual organs is usually of little value in distinguishing *P. parasitica* and *P. infestans*. *P. boehmeriae*, however, is unique in producing oogonia and amphigynous antheridia promptly and abundantly.

The average diameters of the oogonia of species with paragynous antheridia are: *P. cactorum*. 27.9μ; *P. citricola*, 27.0μ; *P. hibernalis*, 28.4μ; *P. syringae*, 28.4μ. Different isolations of *P. cactorum* vary in average diameters of oogonia from 26.8μ to 29.4μ. A comparison of the average diameters of oospores shows like variations. *P. cactorum* produces oospores averaging 25.1μ; *P. citricola*, 24.2μ; *P. hibernalis*, 25.7μ; *P. syringae*, 25.0μ. All fall within the range of the average diameters of different isolations of *P. cactorum;* which is 24.2μ to 26.5μ.

A consideration of the species with amphigynous antheridia shows that *P. parasitica*, of which oogonia were measured for 35 isolations, has oogonia averaging 26.4μ in diameter with a range of 21.5μ to 30.4μ, excluding isolations from which fewer than 25 were measured. Oospores average 22.8μ, with a range, for different isolations, of 16.9μ to 27.1μ. Ashby (8) divided the species into two groups; *Microspora*, with oospores

averaging less than 20μ, and *Macrospora*, with oospores more than 20μ in diameter. Numerous isolations which fail to produce them can be referred to neither group. Such a division is of some convenience for the classification of isolations which fall definitely into one group or the other. No. 263, however, produces oospores on lima bean agar with an average diameter of 18.9μ, while on oatmeal agar they average 21.4-22.0μ. The group in which No. 263 would be placed would, therefore, depend upon the medium on which the observations were made. The division of the species into groups on the basis of oospore size probably does not assist in clarifying a situation which is already in a confused state, and the writer prefers the name *P. parasitica*, without the addition of a group name.

P. boehmeriae, *P. capsici*, *P. colocasiae*, *P. cryptogea*, *P. hydrophila*, *P. infestans*, *P. mexicana*, *P. nicotianae*, *P. richardiae* and *P. drechsleri* produce oogonia with amphigynous antheridia and oospores whose average diameters lie within the range of *P. parasitica*.

P. erythroseptica has oogonia and oospores averaging 36.3μ and 31.4μ, respectively. These averages are well above those for any other species, and, since *P. erythroseptica* also differs from the other species in other characters, the use of the larger oogonia and oospores as identifying characters seems justified.

The important facts derived from the morphological data in Table 11 may be summarized briefly: the type of antheridium is characteristic and one type always predominates; the media used do not affect the predominance of the characteristic type; the species producing oospores may be divided into two groups on the basis of the characteristic type of antheridium; species of the group with paragynous antheridia resemble each other very closely in morphology of the sexual organs and cannot be separated on the basis of oogonium or oospore characters; species of the group with amphigynous antheridia vary more widely, but, with one exception, the species all lie within the limits of oogonium and oospore size exhibited by different isolations of *P. parasitica*; *P. erythroseptica* may be separated from the other species by its larger oogonia and oospores.

It has been stated that the formation of sporangia may sometimes be stimulated by placing sterile mycelium in Petri's solution. Mycelium of *P. erythroseptica*, after one week, developed a few large oogonia with amphigynous antheridia. The oogonia were 30.1 to 64.3μ (average 45.1μ) in diameter. No oospores were observed. The writer was unable to make further use of this method but it seems advisable to test its value for obtaining sexual spores more promptly and making earlier identification possible.

Mycelium of No. 173 (*P. cinnamomi*) producing vesicles was placed in M/100 potassium nitrate solution. After 8 days oogonia and oospores were fairly abundant. The oogonia were 22.5-35.9 (average 28.1)μ; oospores, 20.9-33.4 (average 25.7)μ. The antheridia were amphigynous. Of the five isolations of *P. cinnamomi* examined only No. 173 produced oogonia. Ashby (11) has recently found a few oospores of *P. cinnamomi* in old oatmeal agar cultures.

INOCULATIONS

Fruits and Tubers

Inoculations of apple fruits were made by placing mycelium and spores from cultures 2 to 3 weeks old on oatmeal agar in small slits about 3 mm. deep. The wounds were covered with petrolatum to prevent possible drying of the inoculum or tissues before infection occurred. Inoculated plant parts were kept at room temperature and humidity, except those inoculated with *P. infestans*, *P. phaseoli*, *P. syringae*, and *P. hibernalis*, which fail to grow on culture media at room tempeatures in Porto Rico. Inoculations with these species were held at about 10° C. Checks, wounded but not inoculated, were maintained under the same conditions as the inoculated plants or plant parts in all the series of inoculations.

Fig. 13.—*P. cactorum*. Grimes Golden apples photographed 4 days after inoculation with Nos. 179 and 184.

Apple fruits and cotton bolls.—Table 12 shows the results of inoculations of bolls of Sea Island cotton and apple fruits. The cotton bolls were inoculated in a greenhouse and were not detached from the plants. The wounds were not covered with petrolatum, but each inoculated boll was covered with an oiled paper bag containing a piece of absorbent cotton saturated with water. The cotton was not in contact with the boll.

Infected apples become slightly brown on the exterior in a circular area spreading regularly from the wound (Fig. 13). The tissue beneath becomes slightly brown, slightly soft or spongy and mealy or granular; the vascular tissues are more deeply browned. No soft wet rot occurs. (Fig. 14). The species may be grouped according to their pathogenicity to apples, as follows:

Virulently pathogenic	Weakly pathogenic	Nonpathogenic
P arecae	*P. cambivora*	*P. colocasiae*
P. boehmeriae	*P. cryptogea*	*P. infestans*
P. cactorum	*P. erythroseptica*	*P. phaseoli*
P. capsici	*P. drechsleri*	*P. richardiae*
P. cinnamomi		
P. citricola		
P. citrophthora		
P. hibernalis		
P. hydrophila		
P. meadii		
P. mexicana		
P. nicotianae		
P. palmivora		
P. parasitica		
P. syringae		

Since most species grow rapidly in apple tissues the use of apples for the isolation of Phytophthoras from infected plant parts has proven very successful. The writer has inoculated fruits with bits of infected tissues by the method described. The Phytophthora grows out into the apple tissue quite rapidly and may usually be isolated in pure culture from the margin of the invaded region. The method is especially valuable for isolations from roots where saprophytes, especially Fusaria and bacteria, are numerous. The writer was able to isolate *P. cinnamomi* from roots of avocado trees and *P. palmivora* from roots of snapdragons in Porto Rico and to obtain the species in pure culture in nearly every trial. Whether the species which grow weakly in apples can be isolated by this method may depend upon the aggressiveness of the accompanying organisms.

P. colocasiae may be separated from *P. palmivora* very easily by its failure to infect apples. *P. richardiae* may be distinguished from *P. cryptogea* by this character.

Two isolations of *P. palmivora* (Nos. 116 and 272) proved rather weakly virulent. These cultures have consistently been slow, weak growers on all media.

Inoculations with weakly and non-pathogenic isolations were repeated 3 or 4 times at long intervals without important variation in the results.

TABLE 12.—RESULTS OF INOCULATIONS OF WOUNDED MATURE GRIMES GOLDEN APPLE (PYRUS MALUS L.) FRUITS AT COLUMBIA, MO., OCT. AND NOV., 1926 AND JAN. 1930; AND WOUNDED IMMATURE COTTON (GOSSYPIUM BARBADENSE L.) BOLLS AT MAYAGUEZ, P. R. 1926-1929

(Five Apple Fruits Were Inoculated with Each Culture)

No.	Species	Apple fruits		Cotton bolls	
		No. infected after 4 days	Average diameter of infected areas. mm.	No. inoculated	No. infected after 7 days
153	P. arecae	5	22	5	0
*266	P. boehmeriae	5	20	5	0
192	P. cactorum	4	13	10	1
194	" "	5	38	10	1
179	" "	5	29	5	0
184	" "	5	36	10	1
189	" "	5	31	5	0
193	" "	5	33	5	0
168	" "	5	27	5	0
172	" "	5	24	5	0
200	" "	5	28	10	1
210	" "	5	31	5	0
190	" "	5	30	5	0
243	" "	5	34	5	0
149	" "	5	21	5	0
160	" "	3	22	5	0
196	" "	5	48	5	4 sl.
198	P. cambivora	4	11	5	0
208	" "	4	17	5	0
147	P. capsici	4	21	5	0
253	" "	5	34	5	0
173	P. cinnamomi	4	22	5	0
174	" "	5	20	5	0
195	" "	5	22	10	1
242	" "	5	29	5	0
244	" "	5	30	5	0
*267	P. citricola	5	33	5	0
154	P. citrophthora	5	24	5	0
*221	" "	5	49	5	0
*222	" "	5	52	5	0
152	P. colocasiae	0	0	5	0
239	" "	0	0	5	0
150	P. cryptogea	2	9	5	0
176	P. erythroseptica	1	sl.	5	0
†246	P. hibernalis	4	35		
241	P. hydrophila	5	38	10	5
†245	P. infestans	0	0	-	-
†248	" "	0	0		
223	P. meadii	5	53	10	4
238	" "	5	67	10	3
*257	" "	4	17	5	4
148	P. mexicana	3	19	5	0
216	P. nicotianae	5	69	5	1 sl.
232	" "	5	70	10	5
247	" "	5	41	10	7
*271	P. palmivora (typ.)	5	23	5	0
12	" "	5	28	10	1
123	" "	5	42	10	7
236	" "	5	62	5	0
13	" "	5	28	10	2
127	" "	5	18	5	0
137	" "	5	34	5	0
249	" "	5	25	5	0
250	" "	5	28	10	5
*265	" "	5	22	5	4
1	" "	5	32	5	0
3	" "	5	41	10	2
17	" "	5	15	5	0
16	" "	5	32	10	5
9	" "	5	42	5	5
14	" "	5	40	10	2
*272	" "	3	14	5	0
235	" "	5	52	5	0
146	" "	5	19	5	0
4	" "	5	46	10	3
5	" "	5	39	5	0
7	" "	5	42	5	0
255	P. palmivora (atyp.)	4	33	10	2 sl.
180	" "	5	28	5	0
126	" "	5	34	5	0
136	" "	4	12	5	0
97	" "	5	34	10	5

TABLE 12.—(CONTINUED)

No.	Species	Apple fruits		Cotton bolls	
		No. infected after 4 days	Average diameter of infected areas. mm.	No. inoculated	No. infected after 7 days
102	" "	5	37	5	0
116	" "	2	sl.	5	0
140	" "	5	31	5	0
15	" "	5	35	5	0
138	" "	5	19	10	2
18	" "	5	34	10	5
22	" "	5	38	10	5
26	" "	3	13	5	0
36	" "	5	38	10	3
44	" "	5	40	5	0
100	" "	5	32	5	0
121	" "	5	22	5	0
6	" "	5	26	5	0
130	" "	5	36	5	0
141	" "	5	32	5	0
254	" "	5	27	5	0
185	P. parasitica	5	31	5	0
228	" "	5	58	5	5
*268	" "	5	44	5	4
183	" "	5	31	10	7
209	" "	5	36	5	5
*260	" "	5	22	5	5
*269	" "	5	35	5	0
144	" "	5	19	5	0
178	" "	5	33	5	0
2	" "	5	34	5	0
8	" "	5	36	5	5
10	" "	5	39	5	5
11	" "	5	40	5	4
258	" "	5	33	5	4
142	" "	5	17	5	0
*261	" "	5	35	5	4
*262	" "	5	34	5	5
165	" "	5	35	10	4
211	" "	5	51	5	5
212	" "	5	69	5	4
*270	" "	3	32	5	5
132	" "	5	38	5	4
162	" "	5	29	5	0
177	" "	5	28	5	5
181	" "	5	39	10	6
186	" "	5	26	10	4
187	" "	5	36	10	7
191	" "	5	35	5	4
251	" "	5	37	10	4
*264	" "	5	35	5	5
143	" "	5	35	5	0
217	" "	5	39	5	0
259	" "	5	39	5	0
159	" "	5	56	5	0
169	" "	5	31	5	0
175	" "	5	26	5	5
204	" "	5	19	5	4
234	" "	5	56	5	5
139	" "	5	24	10	7
161	" "	5	28	10	6
182	" "	5	25	10	5
201	" "	5	36	5	5
202	" "	5	57	8	4
213	" "	5	38	5	4
252	" "	5	31	10	4
197	" "	5	36	5	0
203	" "	5	33	10	4
207	" "	5	41	5	4
145	" "	5	34	5	0
*263	" "	5	42	5	5
151	" "	5	41	10	6
164	" "	5	28	10	4
166	" "	5	40	10	4
167	" "	5	28	5	0
171	" "	5	32	5	4
199	" "	5	20	5	0
205	" "	5	30	5	5
*274	P. phaseoli	0	0		
227	P. richardiae	0	0	5	0
†156	P. syringae	5	48	-	-
†230	" " "	5	38		
206	P. drechsleri	4	14	5	0

*Inoculations on mature York Imperial apples.
†Inoculated apples kept at 10°C. for 19 days.
sl—slight.

The positive results obtained with *P. cactorum* agree with those obtained by Osterwalder (147) (148), Whetzel and Rosenbaum (233), Wormald (240), Lafferty and Pethybridge (113), and Cooper and Porter (48).

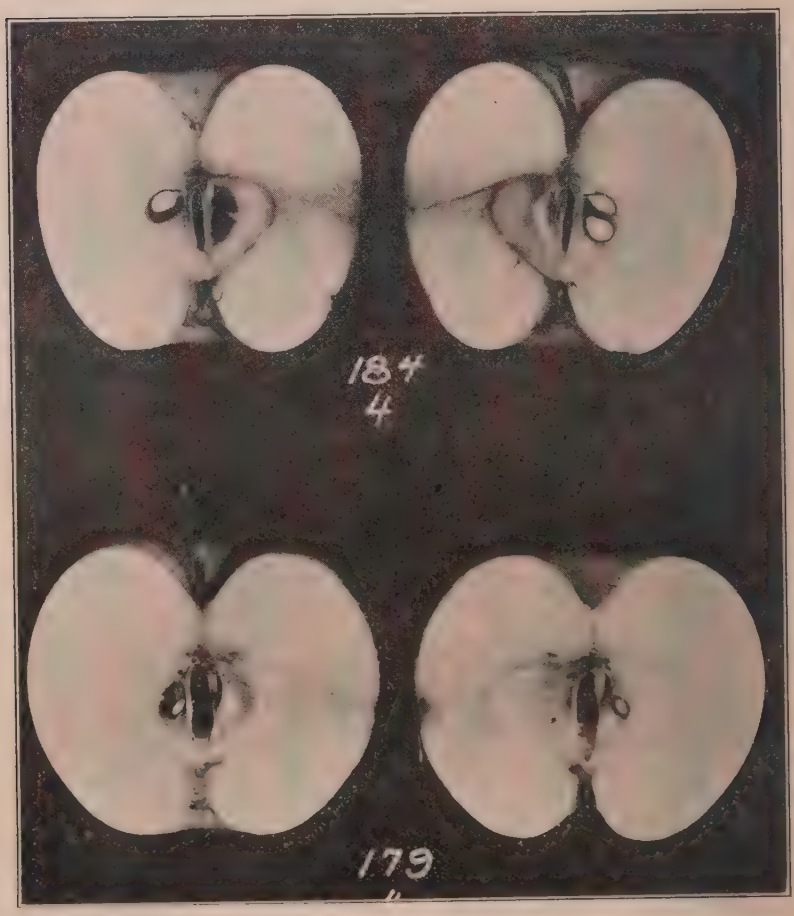

Fig. 14.—*P. cactorum*. Grimes Golden apples cut to show the penetration of the tissues and the browning of the fibro-vascular bundles by Nos. 179 and 184. Photographed 4 days after inoculation.

P. cryptogea was reported pathogenic to apples by Pethybridge and Lafferty (162); *P. citricola*, by Sawada (189); *P. nicotianae*, by Tisdale and Kelley (225); *P. palmivora*, by Reinking (177); *P. parasitica*, by Godfrey (86); *P. syringae*, by Lafferty and Pethybridge (113); *P. tabaci*, by Sawada (189).

Daster (52) failed to infect apples with *P. parasitica.*

The cotton boll inoculations reveal decided variations in pathogenicity among isolations of *P. palmivora* and *P. parasitica.* All isolations from cotton (Nos. 8, 9, 10 and 11) are pathogenic. Among other isolations from a common host there is no uniformity; for example, of 13 isolations of *P. palmivora* from cacao 4 are pathogenic and 9 are not. Numerous isolations of *P. parasitica* rot every inoculated boll while others cause no infection. The following species resemble *P. palmivora* and *P. parasitica* in their pathogenicity to cotton: *P. hydrophila*, *P. meadii*, and *P. nicotianae.* The following are only very slightly virulent or non-pathogenic: *P. arecae*, *P. boehmeriae*, *P. cactorum*, *P. cambivora*, *P. capsici*, *P. cinnamomi*, *P. citricola*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. erythroseptica*, *P. mexicana*, *P. richardiae* and *P. drechsleri.*

Of the above weakly or non-pathogenic species the only ones of which more than one isolation was used are *P. cactorum*, *P. capsici*, *P. cambivora*, *P. cinnamomi*, *P. citrophthora* and *P. colocasiae.* Little significance attaches to the failure of a single isolation to cause infection. Hopkins (98) reported *P. palmivora* and *P. parasitica* from cotton pathogenic and Dade (50) found *P. palmivora* (No. 9) pathogenic to bolls. Ashby (9) stated, "It is probable that any strain of *P. palmivora* will infect. . . unwounded bolls of Egyptian and Sea Island cotton and that the ability to do so is not lost readily in pure culture." The writer inoculated bolls with 43 isolations of *P. palmivora* and found 27 of them non-pathogenic. Some of the most recent isolations (Nos. 254, 255 and 271) are among the non-pathogenic group while some of the old cultures (Nos. 18 and 22) are pathogenic; the differences in virulence cannot be attributed to age in culture.

Mitra (137) obtained infections of inoculated bolls using *P. parasitica* from cotton and Ricinus seedlings and guava fruits.

Potato tubers.—Potato tubers were wound-inoculated under laboratory conditions. Since the purpose of the experiment was to determine the ability of the isolations to grow in the tissues, no special effort was made to prevent subsequent bacterial contamination. The soft, watery, ill-smelling decay which frequently follows fungus invasion is probably largely bacterial. It never occurred among the check tubers.

TABLE 13.—RESULTS OF INOCULATIONS OF WOUNDED POTATO (SOLANUM TUBEROSUM L.) TUBERS, AT COLUMBIA, MISSOURI, APRIL, 1927 AND FEB., 1930 ON EARLY ROSE AND RUSSET; AT MAYAGUEZ, P. R. SEPT., 1927 ON AN UNKNOWN VARIETY

(Five Tubers Were Inoculated With Each Isolation.)

No.	Species	Type of infection after 10 days	Extent of infection after 10 days
153	P. arecae	Soft. Pink.	Complete.
256	P. boehmeriae	No infection.	
192	P. cactorum	No infection.	
194	" "	Soft. Pink.	Nearly complete.
179	" "	Soft. Pink.	¼-¾ of tubers.
184	" "	Soft. Pink.	Complete.
189	" "	Soft. Pink.	½ of tubers.
193	" "	Soft. Pink.	½ of tubers.
168	" "	Leathery. Pink.	Complete.
172	" "	Soft. Pink.	¾ of tubers.
200	" "	Soft. Pink.	Nearly complete.
210	" "	Soft. Pink.	¼-½ of tubers.
190	" "	Soft. Pink.	¼-½ of tubers
243	" "	Soft. Pink.	Complete.
149	" "	Soft. Pink.	¾ of tubers.
160	" "	Soft. Pink.	Complete.
196	" "	Soft. Pink.	Nearly complete.
198	P. cambivora	No infection.	
208	" "	No infection.	
147	P. capsici	Soft. Pink.	¼ of tubers.
*253	" "	Soft. Pink.	Complete.
*173	P. cinnamomi	Dry. Brown.	Slight.
*174	" "	Dry. Brown.	Slight.
195	" "	Soft. Pink.	½ of tubers.
*242	" "	Leathery. Pink.	Complete.
*244	" "	Leathery. Pink.	Complete.
267	P. citricola	No infection.	
154	P. citrophthora	Soft. Pink.	Nearly complete.
221	" "	Soft. Pink.	Nearly complete.
222	" "	Soft. Pink.	Nearly complete.
152	P. colocasiae	No infection.	
*239	" "	No infection.	
150	P. cryptogea	Soft. Pink.	Nearly complete.
176	P. erythroseptica	Soft. Pink.	Complete.
†246	P. hibernalis	No infection.	
*241	P. hydrophila	Leathery. Pink.	Complete.
†245	P. infestans	No infection.	
†248	" "	Dry. Brown.	¼ of tubers.
*223	P. meadii	Soft. Pink.	Complete.
*238	" "	Soft. Pink.	Complete.
257	" "	Soft. Pink.	Complete.
148	P. mexicana	Soft. Pink.	Complete.
216	P. nicotianae	Soft. Pink.	Complete.
*232	" "	Soft. Pink.	Complete.
*247	" "	Soft. Pink.	Complete.
271	P. palmivora (typ.)	Leathery. Pink	Complete.
12	" "	Dry. Brown.	Slight.
123	" "	Leathery. Pink.	½ of tubers.
*236	" "	Leathery. Pink.	Complete.
13	" "	Leathery. Pink.	Complete.
127	" "	Soft. Pink.	Complete.
137	" "	Soft. Pink.	½ of tubers.
*249	" "	Leathery. Pink.	Complete.
*250	" "	Leathery. Pink.	Complete.
265	" "	Leathery. Pink.	¼ of tubers.
1	" "	Leathery. Pink.	Complete.
3	" "	Leathery. Pink.	½ of tubers.
17	" "	No infection.	
16	" "	Leathery. Pink.	½ of tubers.
9	" "	Soft. Pink.	Nearly complete.
14	" "	Leathery. Pink	Nearly complete.
*235	" "	Soft. Pink.	Complete.
146	" "	Leathery. Pink.	¼-½ of tubers.
4	" "	Soft. Pink.	Nearly complete.
5	" "	Soft. Pink.	Complete.
7	" "	Leathery. Pink.	Nearly complete.
255	P. palmivora (atyp.)	Leathery. Pink.	¼-¾ of tubers.
180	" "	Leathery. Pink.	¼-½ of tubers.
126	" "	No infection.	

TABLE 13.—(CONTINUED)

No.	Species	Type of infection after 10 days	Extent of infection after 10 days
136	" "	No infection	
97	" "	Soft. Pink.	Complete.
102	" "	Soft. Pink.	Complete.
116	" "	No infection.	
140	" "	No infection	
15	" "	Leathery. Pink.	Complete.
138	" "	Soft. Pink.	¼ of tubers.
18	" "	Soft. Pink.	Complete.
22	" "	Soft. Pink.	Complete.
26	" "	Soft. Pink.	Complete.
36	" "	Soft. Pink.	Complete.
44	" "	Soft. Pink.	Complete.
100	" "	Soft. Pink.	Complete.
*121	" "	Leathery. Pink.	Complete.
6	" "	Leathery. Pink.	½ of tubers.
130	" "	Soft. Pink.	Complete.
141	" "	Soft. Pink.	Complete.
254	" "	No infection.	
185	P. parasitica	No infection.	
*228	" "	Soft. Pink.	Complete.
268	" "	Leathery. Black.	¼-½ of tubers
183	" "	Soft. Pink.	Nearly complete.
209	" "	Soft. Pink.	Complete.
260	" "	Soft. Pink.	Complete.
269	" "	Soft. Pink.	Complete.
144	" "	Leathery. Pink.	¼-½ of tubers.
178	" "	Leathery. Pink.	¼ of tubers.
2	" "	Soft. Pink.	Complete.
8	" "	Soft. Pink.	Complete.
10	" "	Soft. Pink.	Nearly complete.
11	" "	Soft. Pink.	½ of tubers.
142	" "	Soft. Pink.	Complete.
261	" "	Soft. Pink.	Complete.
262	" "	Soft. Pink.	Complete.
165	" "	Soft. Pink.	Complete.
211	" "	Soft. Pink.	¼-½ of tubers.
212	" "	Soft. Pink.	Nearly complete.
270	" "	Soft. Pink.	Complete.
132	" "	Soft. Pink.	Nearly complete.
162	" "	Soft. Pink.	Nearly complete.
177	" "	Soft. Pink.	¼-¾ of tubers.
181	" "	Soft. Pink.	Complete.
186	" "	Soft. Pink.	Nearly complete.
187	" "	Leathery. Pink.	¼ of tubers.
191	" "	Soft. Pink.	Nearly complete.
*251	" "	Soft. Pink.	Complete.
264	" "	Soft. Pink.	Complete.
143	" "	Soft. Pink.	Complete.
217	" "	Soft. Pink.	Complete.
259	" "	Soft. Pink.	Nearly complete.
159	" "	Soft. Pink.	Nearly complete.
169	" "	Soft. Pink.	Nearly complete.
175	" "	Soft. Pink.	Nearly complete.
204	" "	Soft. Pink.	Nearly complete.
*234	" "	Soft. Pink.	Complete.
139	" "	Soft. Pink.	Nearly complete.
161	" "	Soft. Pink.	Complete.
182	" "	Soft. Pink.	Nearly complete.
201	" "	Soft. Pink.	Complete.
202	" "	Soft. Pink.	½-¾ of tubers.
213	" "	Soft. Pink.	Complete.
*252	" "	Soft. Pink.	Complete.
197	" "	Soft. Pink.	Complete.
203	" "	Soft. Pink.	Complete.
207	" "	Soft. Pink.	Complete.
*145	" "	Soft. Pink.	Complete.
263	" "	Soft. Pink.	Complete.
151	" "	Soft. Pink.	½ of tubers.
164	" "	Soft. Pink.	Nearly complete.
166	" "	Soft. Pink.	Nearly complete.
167	" "	Soft. Pink.	Complete.
171	" "	Soft. Pink.	½ of tubers.
199	" "	Soft. Pink.	Complete.
205	" "	Soft. Pink.	½ of tubers.
258	" "	Leathery. Pink.	Nearly complete.
†274	P. phaseoli	No infection.	
*227	P. richardiae	No infection.	
†156	P. syringae	No infection.	
†230	" "	No infection.	
*206	P. drechsleri	Soft. Pink	Complete.

*Inoculations made in Porto Rico.
†Tubers kept at 10°C. for 20 days.

The results may be summarized as follows: the parenthetic numbers indicate the number of isolations when different isolations of the same species behaved differently.

Pathogenic	Non-pathogenic
P. arecae	*P. boehmeriae*
P. cactorum (14)	*P. cactorum* (1)
P. capsici	*P. cambivora*
P. cinnamomi	*P. citricola*
P. citrophthora	*P. colocasiae*
P. cryptogea	*P. hibernalis*
P. erythroseptica	*P. infestans* (1)
P. hydrophila	*P. palmivora* (6)
P. infestans (1)	*P. parasitica* (1)
P. meadii	*P. phaseoli*
P. mexicana	*P. richardiae*
P. nicotianae	*P. syringae*
P. palmivora (36)	
P. parasitica (56)	
P. drechsleri	

Cut surfaces of infected tubers are usually white, a pink color appearing after exposure to the air for 20 to 30 minutes. After 2 hours the color deepens to dark brown. The development of a pink coloration is characteristic of the rots caused by most pathogenic species except *P. infestans*, which causes a brown rot. In Table 13 Nos. 173, 174, and 12 are stated to cause a brown infection. Each of these isolations invades the tissues so slightly that they can barely be included in the pathogenic group. No. 268 (*P. parasitica*) produces a blackening which is apparent when the tubers are cut. Of the other isolations of *P. parasitica* 55 cause a pink rot and one is non-pathogenic; pink rot may be considered the characteristic result of infection by *P. parasitica*.

Repeated inoculations with the following always give negative results; *P. boehmeriae*, *P. cactorum* (No. 172), *P. cambivora*, *P. citricola*, *P. colocasiae*, *P. hibernalis*, *P. infestans* (No. 245), *P. palmivora* (Nos. 17, 126, 136, 116, 140 and 254), *P. parasitica* (No. 185), *P. phaseoli*, *P. richardiae*, and *P. syringae*.

An occasional isolation of *P. cactorum*, *P. palmivora*, and *P. parasitica* failed to cause infection, but pathogenicity may be considered characteristic of these species. No evidence was obtained regarding the loss of virulence in culture, since the writer has no information regarding the virulence of these isolations when freshly isolated, and it is quite possible that saprophytic strains exist and may be isolated from decaying plants when the causal pathogen is being sought.

The following investigators reported positive results from inoculations with various species: *P. arecae*, Rosenbaum (181); *P. cinnamomi*, Drechsler (62); *P. citrophthora*, Drechsler (62); *P. cryptogea*, Drechsler (62), and Pethybridge and Lafferty (162); *P. erythroseptica*, Pethybridge (159), and Drechsler (62); *P. hydrophila*, Curzi (49); *P. infestans*, numerous writers since 1845; *P. meadii*, Sharples, Norris and others (194) *P. nicotianae*, Tisdale and Kelley (225); *P. palmivora*, Reinking (177), the writer (226), and Thompson (219); *P. parasitica*, Dastur (52) (54), Drechsler (62), Godfrey (86), Sherbakoff (196), and Reddick (174).

Negative results were reported as follows: *P. cactorum*, DeBary (58) *P. pini var. antirrhini* (*P. cactorum?*), Sundararaman and Ramakrishnan (209); *P. citricola*, Sawada (189); *P. heveae*, Thompson (219); *P. syringae*, Lafferty and Pethybridge (113); *P. thalictri*, Clinton (43). Apparently *P. heveae* and *P. thalictri*, of which no cultures have been studied, may be included among the non-pathogenic species.

Cacao fruits.—Cacao fruits were wound-inoculated and the wounds kept moist during the following 72 hours. The results are listed in Table 14.

Fig. 15.—*P. palmivora*. Sections through cacao pods. Left, inoculated with No. 4, from cacao; right, inoculated with No. 1, from coconut. Photographed 3 days after inoculation.

Infections were produced only by certain isolations of *P. palmivora*, *P. parasitica* and *P. meadii*, with one of 15 fruits inoculated with *P. nicotianae* becoming infected. Twenty isolations of *P. palmivora* each infected one or more fruits. Of these 20 isolations 13 were from cacao in Ceylon, Trinidad, Java and the Philippines. The remaining 7 pathogenic isolations were obtained from *Carica papaya* (Philippines), *Citrus sp.* (Porto Rico) (2), *Erythrina sp.* (Java), and *Hevea brasiliensis* (Ceylon

TABLE 14.—RESULTS OF INOCULATIONS OF NEARLY MATURE WOUNDED CACAO (THEOBROMA CACAO L.) FRUITS. AUG., 1925, SEPT., OCT., NOV., AND DEC., 1927 AND JUNE, 1929. MAYAGUEZ, P. R.

No.	Species	No. inoculated	No. infected after 5 days	Average diameter of infected areas after 5 days cm.
153	P. arecae	5	0	----
266	P. boehmeriae	5	0	----
192	P. cactorum	5	0	----
194	" "	5	0	----
179	" "	5	0	----
184	" "	5	0	----
189	" "	5	0	----
193	" "	5	0	----
168	" "	5	0	----
172	" "	5	0	----
200	" "	5	0	----
210	" "	5	0	----
190	" "	5	0	----
243	" "	5	0	----
149	" "	5	0	----
160	" "	5	0	----
196	" "	5	0	----
198	P. cambivora	5	0	----
208	" "	5	0	----
147	P. capsici	5	0	----
253	" "	5	0	----
173	P. cinnamomi	5	0	----
174	" "	5	0	----
195	" "	5	0	----
242	" "	5	0	----
244	" "	5	0	----
267	P. citricola	5	0	----
154	P. citrophthora	5	0	----
221	" "	5	0	----
222	" "	5	0	----
152	P. colocasiae	5	0	----
239	" "	5	0	----
150	P. cryptogea	5	0	----
176	P. erythroseptica	5	0	----
241	P. hydrophila	5	0	----
223	P. meadii	5	0	----
238	" "	5	1	9.0
257	" "	5	2	9.0
148	P. mexicana	5	0	----
216	P. nicotianae	5	0	----
232	" "	5	1	11.0
247	" "	5	0	----
271	P. palmivora (typ.)	5	0	----
12	" "	8	0	----
123	" "	5	0	----
236	" "	5	0	----
13	" "	5	0	----
127	" "	10	3	6.0
137	" "	5	0	----
249	" "	5	3	5.5
250	" "	5	3	4.5
265	" "	5	0	----
1	" "	10	0	----
3	" "	10	0	----
17	" "	5	0	----
16	" "	5	0	----
9	" "	5	0	----
14	" "	8	5	6.0
272	" "	5	0	----
235	" "	5	0	----
146	" "	5	0	----
4	" "	9	9	7.5
5	" "	8	7	7.5
7	" "	8	7	7.0
255	P. palmivora (atyp.)	5	0	----
180	" "	5	0	----
126	" "	10	0	----
136	" "	5	0	----
97	" "	10	8	6.5
102	" "	10	4	7.5
116	" "	10	5	6.0
140	" "	5	0	----

TABLE 14.—(CONTINUED)

No.	Species	No. inoculated	No. infected after 5 days	Average diameter of infected areas after 5 days cm.
15	" "	5	0	----
138	" "	10	0	----
18	" "	5	5	7.0
22	" "	5	5	6.5
26	" "	10	2	5.0
36	" "	5	5	7.5
44	" "	5	5	8.0
100	" "	5	5	8.0
121	" "	10	6	5.0
6	" "	8	1	3.0
130	" "	5	5	6.5
141	" "	10	4	8.0
254	" "	5	0	----
185	P. parasitica	5	0	----
228	" "	5	0	----
268	" "	5	0	----
183	" "	5	4	1.5
209	" "	5	0	----
260	" "	5	2	11.0
269	" "	5	0	----
144	" "	10	0	----
178	" "	5	0	----
2	" "	5	0	----
8	" "	8	5	6.5
10	" "	5	0	----
11	" "	8	5	6.0
258	" "	5	0	----
142	" "	10	0	----
261	" "	5	1	12.5
262	" "	5	0	----
165	" "	5	0	----
211	" "	5	4	12.0
212	" "	5	0	----
270	" "	5	1	8.0
132	" "	5	0	----
162	" "	5	0	----
177	" "	5	0	----
181	" "	5	4	12.0
186	" "	5	0	----
187	" "	5	0	----
191	" "	5	0	----
251	" "	5	3	13.5
264	" "	5	0	----
143	" "	10	0	----
217	" "	5	0	----
259	" "	5	0	----
159	" "	5	0	----
169	" "	5	0	----
175	" "	5	0	----
204	" "	5	0	----
234	" "	5	2	8 5
139	" "	5	0	----
161	" "	5	0	----
182	" "	5	0	----
201	" "	5	0	----
202	" "	5	0	----
213	" "	5	0	----
252	" "	5	0	----
197	" "	5	1	6.0
203	" "	5	3	9.0
207	" "	5	5	10.5
145	" "	5	0	----
263	" "	5	0	----
151	" "	5	0	----
164	" "	5	0	----
166	" "	4	2	4.0
167	" "	5	0	----
171	" "	5	0	----
199	" "	5	0	----
205	" "	5	0	----
227	P. richardiae	5	0	----
206	P. drechsleri	5	0	----

and Java) (3). However, two others from *C. papaya*, one other from *Citrus sp.* and one other from *H. brasiliensis* were non pathogenic. All cacao isolations were somewhat pathogenic. These results indicate that biologic specialization exists in *P. palmivora*, and that the strains capable of infecting cacao appear, in nature, to be confined fairly closely to that host and a few others ordinarily growing in close association with it. The type of infection is illustrated by Fig. 15.

Reinking (177) reported infections of cacao fruits with isolations from coconut palms in the Philippines, but later inoculations by Ashby (6), the writer (227), Gadd (82) (83) and Dade (50) did not confirm his observations. Rutgers (185) reported isolations from cacao in Java pathogenic while one from *Myristica fragrans* was not. Gadd (81) and Dade (50) inoculated fruits with several isolations but were able to secure prompt infections with cacao isolations only.

P. parasitica proved quite variable as to pathogenicity to wounded fruits, 14 of 57 isolations exhibiting various degrees of virulence. The 14 pathogenic isolations were from *Capsicum annuum*, *Catharanthus roseus*, *Gossypium barbadense* (2), *Hibiscus sabdariffa*, *Lilium spp.* (2), *Lycopersicon Lycopersicon* (2), *Ricinus communis*, *Solanum tuberosum* (3), and an unknown host (1). Some of these pathogenic isolations grew through and produced a dark discoloration of the tissues more rapidly than any of *P. palmivora*. It is not surprising that *P. parasitica* is occasionally isolated from cacao fruits as was No. 145 by Stahel in Surinam.

Two isolations of *P. meadii* attacked fruits less virulently than *P. palmivora* from cacao. Dastur (53) failed to obtain infection with this species, and McRae (132) found it less virulent than *P. palmivora*.

The other species are non-pathogenic.

Inoculations of unwounded fruits were made by placing mycelium and spores in a drop of water held in place on the surface on the fruit by a ring of petrolatum. All isolations which infected wounded fruits were used. None of the isolations of *P. parasitica*, *P. meadii*, or *P. nicotianae* caused infection. *P. palmivora* (Nos. 4, 5, 7, 18, 26, 44 and 130), all from cacao infected 2 to all of 5 inoculated fruits and caused brown, rotted areas averaging 7 to 12 cm. in diameter after 7 days. Other *P. palmivora* isolations failed to infect.

It is interesting to notice that of the three typical isolations (Nos. 4, 5, and 7), all were pathogenic, while of the atypical cultures (Nos. 18, 22, 26, 36, 44, 100, 121, 6, 130 and 141) only 4 were capable of invading unwounded fruits. These atypical cultures may have undergone changes in aerial growth and spore characters, caused by unfavorable culture

media and temperatures, as Ashby (9) believes possible; the same factors may cause a diminution or loss of virulence.

Sharples, Norris and others (194) observed that *P. meadii* could infect wounded, but not unwounded fruits.

Negative results of inoculations with other species were recorded as follows: *P. pini var. antirrhini* (*P. cactorum*), Sundararaman and Ramakrishnan (209); *P. cactorum*, *P. colocasiae*, *P. jatrophae* (probably *P. parasitica*), and *P. nicotianae*, Rutgers (185).

Tomato and eggplant fruits. Inoculations of wounded green tomato fruits and eggplant fruits are recorded in Table 15. The tomato fruits were half to three-quarters mature in size and the eggplant fruits nearly mature.

The cultures may be grouped, according to their pathogenicity to green tomato fruits, in three divisions; the numbers in parentheses indicate the number of isolations:

Virulently pathogenic	Very weakly pathogenic	Non-pathogenic
P. cactorum (3)	*P. boehmeriae*	*P. arecae*
P. capsici (2)	*P. cactorum* (6)	*P. cactorum* (6)
P. citrophthora (3)	*P. cinnamomi* (3)	*P. cambivora*
P. cryptogea	*P. citricola*	*P. cinnamomi* (2)
P. erythroseptica	*P. meadii* (1)	*P. colocasiae*
P. hydrophila	*P. nicotianae* (1)	*P. palmivora* (typ.) (8)
P. meadii (2)	*P. palmivora* (typ.) (8)	*P. palmivora* (atyp.) (10)
P. mexicana	*P. palmivora* (atyp.) (5)	*P. parasitica* (9)
P. nicotianae (2)	*P. parasitica* (6)	*P. richardiae*
P. palmivora (typ.) (6)	*P. drechsleri*	
P. palmivora (atyp.) (5)		
P. parasitica (42)		

Different isolations of the same species show marked variations in pathogenicity. *P. cactorum* cultures are usually weakly to non-pathogenic; *P. meadii* and *P. nicotianae*, weakly to virulently pathogenic; *P. palmivora* typical and atypical cultures are similar in behavior, both groups varying from virulently to non-pathogenic; *P. parasitica* is usually pathogenic but about one of six isolations fail to infect. Typical infections by virulently pathogenic isolations are illustrated by Fig. 16.

The following species have been reported pathogenic to fruits in inoculation experiments: *P. cryptogea*, Pethybridge and Lafferty (162); *P. hydrophila*, Curzi (49); *P. nicotianae*, Tisdale and Kelley (225); *P. palmivora*, Reinking (177), the writer (226) and Ocfemia and Roldan (146); *P. parasitica*, Sherbakoff (196), Godfrey (86), Tisdale and Kelley (225) and Williams (234).

Negative results were reported for *P. cactorum* (*P. paeoniae*) by Cooper and Porter (48) and Sundararaman and Ramakrishnan (209),

TABLE 15.—RESULTS OF INOCULATIONS OF WOUNDED GREEN TOMATO (LYCOPERSICON LYCOPERSICON (L.) KARST.) FRUITS AT COLUMBIA, MO., OCT., 1926, MAYAGUEZ, P. R., JULY, 1927 AND YONKERS, N. Y., OCT., 1929; AND WOUNDED EGGPLANT (SOLANUM MELONGENA L.) FRUITS AT MAYAGUEZ, P. R., JULY, 1926, JULY, 1927, AND JUNE, 1929

(Five Fruits of Each Were Inoculated With Each Isolation.)

No.	Species	Tomato fruits		Eggplant fruits	
		No. infected after 96 hrs.	Degree of infection	No. infected after 48 hrs.	Degree of infection
153	P. arecae	0	--------	0	--------
266	P. boehmeriae	3	slight	0	--------
192	P. cactorum	0	--------	0	--------
194	" "	0	--------	0	--------
179	" "	5	moderate	0	--------
184	" "	2	slight	5	moderate
189	" "	1	slight	3	moderate
193	" "	1	slight	3	slight
168	" "	5	severe	0	--------
172	" "	1	slight	0	--------
200	" "	4	moderate	0	--------
210	" "	0	--------	0	--------
190	" "	0	--------	0	--------
243	" "	1	slight	0	--------
149	" "	0	--------	0	--------
160	" "	0	--------	2	moderate
196	" "	3	slight	0	--------
198	P. cambivora	0	--------	0	--------
208	" "	0	--------	0	--------
147	P. capsici	5	severe	5	severe
253	" "	5	severe	5	severe
173	P. cinnamomi	0	--------	0	--------
174	" "	2	slight	0	--------
195	" "	0	--------	0	--------
242	" "	1	slight	0	--------
244	" "	2	slight	0	--------
267	P. citricola	2	slight	0	--------
154	P. citrophthora	5	severe	5	severe
*221	" "	5	severe	2	moderate
*222	" "	5	severe	4	severe
152	P. colocasiae	0	--------	0	
239	" "	0	--------	0	
150	P. cryptogea	5	severe	5	severe
176	P. erythroseptica	4	severe	0	
†246	P. hibernalis	-	--------	0	-
241	P. hydrophila	5	severe	5	severe
†245	P. infestans	-	--------	0	-
†248	" "	-	--------	5	severe
223	P. meadii	2	slight	5	moderate
238	" "	5	moderate	0	--------
257	" "	5	moderate	5	severe
148	P. mexicana	5	severe	5	severe
216	P. nicotianae	4	slight	5	severe
232	" "	5	severe	5	severe
247	" "	5	moderate	5	severe
271	P. palmivora (typ.)	1	moderate	3	moderate
12	" "	2	slight	1	slight
123	" "	0	--------	5	moderate
236	" "	5	slight	4	moderate
13	" "	0	--------	5	moderate
127	" "	0	--------	5	moderate
137	" "	2	slight	5	moderate
249	" "	4	moderate	5	severe
250	" "	5	moderate	5	severe
265	" "	2	moderate	0	--------
1	" "	0	--------	5	slight
3	" "	0	--------	5	moderate
17	" "	0	--------	0	--------
16	" "	4	moderate	5	moderate
9	" "	3	slight	4	severe
14	" "	2	slight	5	moderate
272	" "	0	--------	0	--------
235	" "	3	moderate	3	slight
146	" "	0	--------	1	slight
4	" "	1	slight	2	slight
5	" "	1	slight	3	slight
7	" "	3	slight	5	severe
255	P. palmivora (atyp.)	0	--------	2	moderate
180	" "	1	slight	2	slight
126	" "	0	--------	2	slight
136	" "	0	--------	0	--------
97	" "	5	severe	4	moderate
102	" "	1	slight	5	severe
116	" "	0	--------	0	--------

TABLE 15.—(CONTINUED)

No.	Species	Tomato fruits		Eggplant fruits	
		No. infected after 96 hrs.	Degree of infection	No. infected after 48 hrs.	Degree of infection
140	" "	0	--------	0	--------
15	" "	1	slight	2	slight
138	" "	2	slight	3	moderate
18	" "	0	--------	3	severe
22	" "	1	slight	5	severe
26	" "	0	--------	0	--------
36	" "	4	severe	5	severe
44	" "	5	severe	5	severe
100	" "	5	moderate	5	severe
121	" "	0	--------	4	moderate
6	" "	0	--------	0	--------
130	" "	5	severe	5	severe
141	" "	0	--------	5	severe
254	" "	0	--------	5	moderate
185	P. parasitica	5	severe	0	--------
228	" "	5	moderate	4	severe
268	" "	5	moderate	5	severe
183	" "	5	severe	5	severe
209	" "	5	slight	5	severe
260	" "	5	moderate	4	severe
269	" "	5	severe	5	moderate
144	" "	0	--------	0	--------
178	" "	0	--------	3	slight
2	" "	0	--------	5	slight
8	" "	5	severe	5	severe
10	" "	5	severe	5	severe
11	" "	4	moderate	5	severe
258	" "	5	severe	4	severe
142	" "	0	--------	0	--------
261	" "	4	moderate	5	severe
262	" "	5	severe	5	severe
165	" "	5	severe	5	severe
*211	" "	5	severe	5	severe
212	" "	5	severe	5	severe
270	" "	5	moderate	5	severe
132	" "	5	moderate	5	severe
162	" "	5	severe	4	moderate
177	" "	5	severe	5	severe
181	" "	5	severe	2	moderate
186	" "	5	severe	5	moderate
187	" "	5	severe	5	moderate
191	" "	5	severe	5	severe
251	" "	5	moderate	5	severe
264	" "	3	moderate	3	slight
143	" "	0	--------	4	slight
*217	" "	3	slight	5	moderate
259	" "	5	moderate	5	severe
159	" "	2	moderate	5	slight
169	" "	5	severe	3	slight
175	" "	0	--------	5	severe
204	" "	1	slight	4	moderate
234	" "	5	severe	5	severe
139	" "	2	slight	5	severe
161	" "	5	severe	5	severe
182	" "	5	severe	5	severe
*201	" "	5	severe	5	severe
*202	" "	5	severe	5	severe
213	" "	5	severe	4	moderate
252	" "	5	severe	5	severe
197	" "	5	slight	3	slight
203	" "	0	--------	0	--------
207	" "	5	severe	5	severe
145	" "	1	slight	0	--------
263	" "	3	severe	5	severe
151	" "	5	severe	5	severe
164	" "	5	severe	5	severe
166	" "	5	severe	5	severe
167	" "	4	severe	5	slight
171	" "	5	severe	5	severe
199	" "	0	--------	5	moderate
205	" "	0	--------	5	severe
227	P. richardiae	0	--------	0	--------
†156	P. syringae	-	--------	0	--------
†230	" "	-	--------	0	--------
206	P. drechsleri	1	slight	5	severe

*Tomato fruits inoculated at Mayaguez, P. R.
†Inoculated fruits kept at about 10°C. for one week.
Tomato inoculations with numbers 223 and above were made at Yonkers, N. Y.

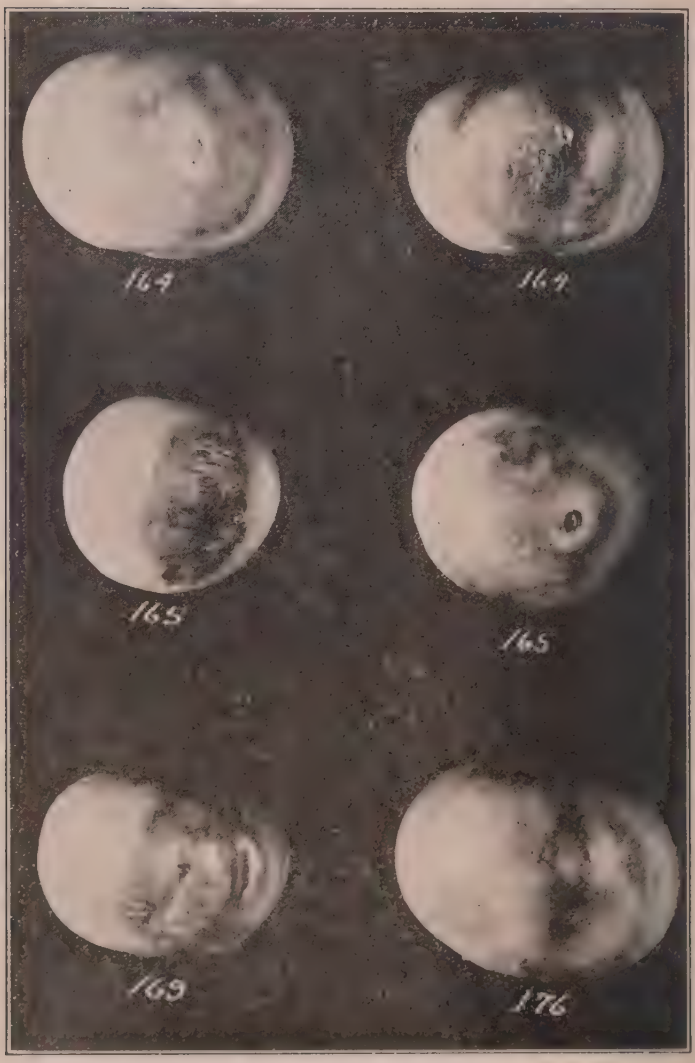

Fig. 16.—Tomato fruits photographed 4 days after inoculation. Nos. 164, 165 and 169, *P. parasitica*; No. 176, *P. erythroseptica*.

using their *P. pini var. antirrhini*, which the writer considers similar to *P. cactorum*; for *P. citricola*, Sawada (189); and for *P. parasitica*, Dastur (52).

Dastur (52) failed to infect wounded fruits with a freshly isolated culture of *P. parasitica* from *Ricinus communis* in India, yet the writer's

Fig. 17.—Eggplant fruits photographed 2 days after inoculation. *P. parasitica*, No. 191 (tomato), No. 201 (eggplant), No. 211 (eggplant) No. 207 (potato), No. 202 (eggplant) (?), No. 209 (pepper), No. 205 (unknown), No. 175 (rhubarb), No. 212 (Lilium), No. 171 (unknown); *P. parasitica var. nicotianae*, No. 216; *P. capsici*. No. 147.

No. 234 from the same host and locality is quite virulent. This suggests that the failure of some isolations of *P. parasitica* and, possibly, *P. palmivora*, to infect is not due to a loss of virulence in culture but to an inherent characteristic of the particular strain.

A grouping of the isolations according to pathogenicity to eggplant fruits:

Virulently pathogenic	Very weakly pathogenic	Non-pathogenic
P. cactorum (3)	*P. cactorum* (1)	*P. arecae*
P. capsici (2)	*P. palmivora* (typ.) (6)	*P. boehmeriae*
P. citrophthora (3)	*P. palmivora* (atyp.) (3)	*P. cactorum* (11)
P. cryptogea	*P. parasitica* (8)	*P. cambivora*
P. hydrophila		*P. cinnamomi*
P. infestans (1)		*P. citricola*
P. meadii (2)		*P. colocasiae*
P. mexicana		*P. erythroseptica*
P. nicotianae		*P. hibernalis*
P. palmivora (typ.) (13)		*P. infestans* (1)
P. palmivora (atyp.) (13)		*P. meadii* (1)
P. parasitica (44)		*P. palmivora* (typ.) (3)
P. drechsleri		*P. palmivora* (atyp.) (5)
		P. parasitica (5)
		P. richardiae
		P. syringae

Similar variations in pathogenicity of conspecific cultures to eggplant fruits and tomato fruits may be noted. In general *P. palmivora* and *P. parasitica* are more frequently able to attack eggplant than tomato fruits, while *P. cinnamomi* fails to infect eggplants, although 3 cultures are slightly pathogenic to tomato fruits. One culture (No. 245) of *P. infestans* is non-pathogenic and the other (No. 248) causes severe infection; similar results occur with inoculated potato tubers. Fig. 17 shows the results of inoculations with some virulently pathogenic isolations.

Positive inoculations with *P. palmivora* were reported by Ocfemia and Roldan (146) and the writer (227); with *P. hydrophila* by Curzi (49); with *P. tabaci* by Sawada (189). Negative results were obtained with *P. cactorum* (*P. pini var. antirrhini*) by Sundararaman and Ramakrishnan (209); with *P. citricola* by Sawada (189); and with *P. colocasiae* by Thompson (216), using an isolation from *Piper betle* which Ashby (8) later identified as *P. colocasiae*.

Stems and Leaves

Ricinus seedlings.—Stems of Ricinus seedlings were inoculated by placing the inoculum in a small slit in the stem about one and one half inches below the tip. The inoculated plants were in a greenhouse. The results are summarized in Table 16. The cankers or lesions which some species frequently caused were dark brown to nearly black; in severe

cases an area one inch in length and nearly encircling the stem was invaded. Cessation of growth in the canker region caused a bending of the stem as the tissue on the healthy side continued growth. In the killed plants the stem was blackened and completely invaded; the parts above the wound wilted and died as the stem collapsed (Fig. 18). Infection spread downward more slowly than upward due to the more mature, hardened condition of the lower portion of the stem. The fungi frequently spread from the stem into the petioles and caused abscission. Occasionally invasions of very young leaves caused greenish brown, irregular, papery areas of dead tissue.

Fig. 18.—Castor bean (Ricinus) seedlings photographed 3 days after inoculation of the stems with *P. parasitica* from tomato (No. 132) at left and eggplant (No. 201) at right.

One or more isolations of the following species killed at least one of the inoculated seedlings: *P. hydrophila*, *P. meadii*, *P. nicotianae*, *P. palmivora*, *P. parasitica* and *P. capsici*.

The following were non-pathogenic or caused only slight lesions on a small number of the seedlings: *P. arecae*, *P. boehmeriae*, *P. cactorum*, *P. cambivora*, *P. cinnamomi*, *P. citricola*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. erythroseptica*, *P. mexicana*, *P. richardiae* and *P. drechsleri*.

P. nicotianae, *P. palmivora* and *P. parasitica* vary widely in the pathogenicity of different isolations. Of 3 isolations of *P. nicotianae*

TABLE 16.—RESULTS OF INOCULATIONS OF WOUNDED CASTOR BEAN (RICINUS COMMUNIS L.) SEEDLINGS 5 TO 12 INCHES TALL IN SEPT. AND OCT., 1927 AND JULY, 1929 AT MAYAGUEZ, P. R.

No.	Species	No. inoculated	No. killed during 15 days	Av. no. of days from inoculation to death	No. with canker at wound after 15 days
153	P. arecae	5	0	----	0
266	P. boehmeriae	3	0	----	2 sl.
192	P. cactorum	5	0	---	0
194	" "	5	0	----	0
179	" "	5	0	----	0
184	" "	5	0	----	0
189	" "	5	0	----	0
193	" "	5	0	---	0
168	" "	5	0	----	0
172	" "	5	0	--	0
200	" "	5	0	---	0
210	" "	5	0	----	0
190	" "	5	0	----	0
243	" "	5	0	----	0
149	" "	5	0	--	0
160	" "	5	0	--	0
196	" "	5	0	----	0
198	P. cambivora	5	0	----	0
208	" "	5	0	---	0
147	P. capsici	5	0	--	4
253	" "	5	2	2.0	3
173	P. cinnamomi	5	0	---	0
174	" "	5	0	----	0
195	" "	5	0	----	0
242	" "	5	0	-	0
244	" "	5	0	---	0
267	P. citricola	3	0	---	1 sl.
154	P. citrophthora	5	0	--	1
221	" "	5	0	----	0
222	" "	5	0	--	0
152	P. colocasiae	5	0	---	0
239	" "	5	0	----	0
150	P. cryptogea	5	0	--	0
176	P. erythroseptica	5	0	-	0
241	P. hydrophila	5	2	2.0	3
223	P. meadii	5	1	2.0	0
238	" "	5	1	2.0	4
257	" "	5	2	3.0	0
148	P. mexicana	5	0	-	0
216	P. nicotianae	5	0	-	1
232	" "	5	0	-	5
247	" "	5	5	3.8	-
271	P. palmivora (typ.)	3	0	-	3 sl.
12	" "	5	0	-	2
123	" "	5	3	3.3	2
236	" "	5	2	5.0	3
13	" "	5	1	3.0	1
127	" "	5	1	5.0	0
137	" "	5	0	---	2
249	" "	5	4	3.5	1
250	" "	5	0	---	1
265	" "	5	0	---	4
1	" "	5	1	5.0	3
3	" "	5	4	3.5	1
17	" "	5	0	---	0
16	" "	5	2	3.0	3
9	" "	5	3	3.0	2
14	" "	5	4	3.2	0
272	" "	3	0	--	0
235	" "	5	0	---	0
146	" "	5	0	---	1
4	" "	5	1	2.0	4
5	" "	5	0	-	3
7	" "	5	0	-	0
255	P. palmivora (atyp.)	5	5	2.2	-
180	" "	5	0	-	0
126	" "	5	1	5.0	1
136	" "	5	0	-	0
97	" "	5	1	2.0	3
102	" "	5	0	-	1
116	" "	5	0	-	0
140	" "	5	0	-	0

TABLE 16.—(CONTINUED)

No.	Species	No. inoculated	No. killed during 15 days	Av. no. of days from inoculation to death	No. with canker at wound after 15 days
15	" "	5	0	---	0
138	" "	5	1	2.0	3
18	" "	5	1	3.0	2
22	" "	5	1	6.0	1
26	" "	5	0	---	1
36	" "	5	0	---	4 sl.
44	" "	5	2	2.5	2
100	" "	5	1	2.0	2
121	" "	5	1	15.0	2
6	" "	5	0	---	0
130	" "	5	2	2.0	3
141	" "	5	2	4.0	0
254	" "	5	3	3.7	2
185	P. parasitica	5	0	---	0
228	" "	5	2	3.0	3
268	" "	3	1	2.0	1
183	" "	5	1	2.0	4
209	" "	5	2	2.0	3
260	" "	5	5	3.4	-
269	" "	3	0	---	0
144	" "	5	0	---	0
178	" "	5	0	---	0
2	" "	5	0	---	3
8	" "	5	3	3.0	2
10	" "	5	4	2.0	1
11	" "	5	2	3.0	2
258	" "	5	5	2.2	-
142	" "	5	0	---	0
261	" "	5	2	2.5	1 sl.
262	" "	5	3	2.3	2
165	" "	5	1	2.0	4
211	" "	5	2	2.5	3
212	" "	5	4	2.2	1
270	" "	3	1	2.0	2
132	" "	5	4	3.5	1
162	" "	5	3	3.3	2
177	" "	5	1	9.0	4
181	" "	5	0	---	4
186	" "	5	1	2.0	0
187	" "	5	1	2.0	4
191	" "	5	2	4.0	3
251	" "	5	3	3.7	2
264	" "	5	4	3.0	1
143	" "	5	0	---	4
217	" "	5	0	---	0
259	" "	5	3	2.0	1
159	" "	5	0	---	0
169	" "	5	0	---	0
175	" "	5	2	4.5	3
204	" "	5	1	3.0	0
234	" "	5	3	3.3	2
139	" "	5	4	4.5	1
161	" "	5	3	2.0	2
182	" "	5	0	---	5
201	" "	5	5	2.6	-
202	" "	5	3	2.3	2
213	" "	5	4	2.5	1
252	" "	5	3	3.7	2
197	" "	5	0	---	3
203	" "	5	1	3.0	1 sl.
207	" "	5	5	2.0	-
145	" "	5	0	---	0
263	" "	5	3	2.7	2 sl.
151	" "	5	0	---	5
164	" "	5	4	5.0	1
166	" "	5	0	---	5
167	" "	5	3	4.0	1
171	" "	5	4	2.0	1
199	" "	5	1	3.0	0
205	" "	5	5	2.6	-
227	P. richardiae	5	0	---	0
206	P. drechsleri	5	0	---	1 sl.

one killed all inoculated plants, the second killed none but caused lesions on all, while the third produced a lesion on only one plant.

Of the 43 isolations of *P. palmivora* 23 killed one or more plants, 10 caused lesions only and 10 were non-pathogenic. Typical and atypical cultures behaved similarly.

Of 57 isolations of *P. parasitica* 41 caused some killing, 7 caused lesions only and 9 failed to cause infection. *P. parasitica* is slightly more virulent than *P. palmivora*; a larger proportion of the isolations of the former proved pathogenic, and the average number of seedlings killed by each isolation was larger.

Dastur (52) (54) and Tisdale and Kelley (225) reported *P. parasitica* pathogenic to seedlings. Godfrey (86) infected inflorescences. McRae (134) found it difficult to secure infections with an isolation from cotton but one from guava infected seedlings readily.

P. meadii was reported pathogenic to leaves by McRae (131) and Sharples, Norris and others (194) secured infection on 2 of 4 wounded and inoculated stems of seedlings.

P. nicotianae was found pathogenic to very young plants by Palm and Jochems (151), but only slight infections occurred on older ones. Tisdale (224) reported Florida and Java isolations pathogenic and Tisdale and Kelley (225) found *P. nicotianae* equally virulent with *P. parasitica*. Nolla (144) reported a Porto Rico isolation pathogenic.

P. palmivora was reported pathogenic to seedlings by Thompson (219), using an isolation from Hevea.

P. heveae was also reported pathogenic by Thompson (219).

P. citricola was found non-pathogenic by Sawada (189).

Papaw seedlings.—Inoculations of young stems about midway between the base and tip frequently caused a soft, wet, green to black rot followed by the collapse of the stems (Fig. 19). Infections usually spread through the tissues and resulted in death, unlike the infections of Ricinus seedlings which often caused cankers only. The results are incorporated in Table 17.

Isolations causing the death of two or more plants are considered virulently pathogenic, those killing only one plant or causing lesions only on 2 or more plants, as weakly pathogenic. On this basis the isolations may be grouped as follows:

Virulently pathogenic	Weakly pathogenic	Non-pathogenic
P. cactorum (4)	*P. cactorum* (3)	*P. arecae*
P. capsici (1)	*P. capsici* (1)	*P. boehmeriae*
P. hydrophila	*P. colocasiae* (1)	*P. cactorum* (8)
P. mexicana	*P. nicotianae* (1)	*P. cambivora*
P. nicotianae (1)	*P. palmivora* (typ.) (1)	*P. cinnamomi*
P. palmivora (typ.) (13)	*P. palmivora* (atyp.) (3)	*P. citricola*
P. palmivora (atyp.) (3)	*P. parasitica* (15)	*P. citrophthora*
P. parasitica (16)	*P. drechsleri*	*P. colocasiae* (1)
		P. cryptogea
		P. erythroseptica
		P. meadii
		P. nicotianae (1)
		P. palmivora (typ.) (8)
		P. palmivora (atyp.) (15)
		P. parasitica (26)
		P. richardiae

Fig. 19.—Papaw (Carica) seedlings photographed 4 days after inoculation of the stems. Left, *P. parasitica* (No. 151); right, *P. palmivora* (No. 146).

TABLE 17.—RESULTS OF INOCULATIONS OF WOUNDED STEMS OF PAPAW (CARICA PAPAYA L.) SEEDLINGS 4 TO 12 INCHES TALL AT MAYAGUEZ, P. R. SEPT., 1927, JULY AND AUG., 1928, AND JULY, 1929.
(Five Seedlings Were Inoculated With Each Isolation.)

No.	Species	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
153	P. arecae	0	- -	0
266	P. boehmeriae	0		0
192	P. cactorum	0	- -	0
194	" "	1	8.0	2
179	" "	2	10.5	0
184	" "	1	13.0	0
189	" "	0	- - -	0
193	" "	0	- - -	1
168	" "	5	11.0	-
172	" "	0	- -	0
200	" "	0		0
210	" "	1	5.0	0
190	" "	2	10.5	3
243	" "	2	5.5	2
149	" "	0	- - -	0
160	" "	0	- -	0
196	" "	0	- -	1
198	P. cambivora	0	- - -	0
208	" "	0	-	0
147	P. capsici	1	5.0	1
253	" "	5	3.4	-
173	P. cinnamomi	0	- -	0
174	" "	0	- - -	1
195	" "	0	- -	0
242	" "	0	- -	0
244	" "	0	- - - -	0
267	P. citricola	0	-	0
154	P. citrophthora	0	-	0
221	" "	0	- - -	0
222	" "	0	- - -	0
152	P. colocasiae	0	- - -	0
239	" "	1	3.0	0
150	P. cryptogea	0	- -	0
176	P. erythroseptica	0	- - -	0
241	P. hydrophila	3	5.0	0
223	P. meadii	0	- -	0
238	P. meadii	0	- -	0
257	" "	0	-	0
148	P. mexicana	2	13.0	2
216	P. nicotianae	1	3.0	0
232	" "	0	- - -	0
247	" "	5	3.2	-
271	P. palmivora (typ.)	4	5.5	1
12	" "	0	- - - -	2
123	" "	4	5.7	1
236	" "	5	3.6	-
13	" "	5	7.2	-
127	" "	5	4.0	-
137	" "	5	4.0	-
249	" "	5	3.8	-
250	" "	5	4.0	-
265	" "	2	10.0	0
1	" "	2	7.0	2
3	" "	0	- - - -	0
17	" "	0	- - - -	0
16	" "	4	15.5	0
9	" "	2	7.0	2
14	" "	0		0
272	" "	0	- -	0
235	" "	0		0
146	" "	4	5.5	0
4	" "	0	- - -	0
5	" "	0	- - - -	0
7	" "	0	- - -	0
255	P. palmivora (atyp.)	4	5.7	0
180	" "	0	- - - -	0
126	" "	1	9.0	1
136	" "	0	- -	0
97	" "	0	-	0
102	" "	0	-	0
116	" "	0		0
140	" "	0	- -	0
15	" "	0	- -	0

TABLE 17.—(CONTINUED)

No.	Species	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
138	" "	3	8.7	0
18	" "	0	----	0
22	" "	0	- --	0
26	" "	0	-- -	0
36	" "	1	6.0	0
44	" "	0	- --	0
100	" "	0	--	0
121	" "	1	8.0	3
6	" "	0	- --	0
130	" "	0	- ---	0
141	" "	0	---	0
254	" "	3	4.7	0
185	P. parasitica	0	----	0
228	" "	0	----	0
268	" "	0	----	1
183	" "	0	----	3
209	" "	0	----	1
260	" "	0	----	0
269	" "	0	----	0
144	" "	0	----	0
178	" "	0	----	0
2	" "	0	----	0
8	" "	4	6.5	0
10	" "	0	- --	1
11	" "	0	- --	0
258	" "	0	----	0
142	" "	0	- --	0
261	" "	0	----	0
262	" "	0	----	3
165	" "	2	13.0	2
211	" "	2	6.0	1
212	" "	1	11.0	1
270	" "	0	----	2
132	" "	0	----	0
162	" "	1	13.0	4
177	" "	4	5.5	0
181	" "	1	13.0	0
186	" "	1	8.0	2
187	" "	2	6.0	1
191	" "	1	8.0	2
251	" "	0	----	5
264	" "	0	----	0
143	" "	0	----	0
217	" "	0	- -	0
259	" "	0	----	1
159	" "	0	----	0
169	" "	0	- --	3
175	" "	0	-- -	3
204	" "	0	----	0
234	" "	2	6.0	1
139	" "	0	----	0
161	" "	2	4.0	1
182	" "	0	----	4
201	" "	5	4.4	-
202	" "	0	- --	2
213	" "	5	4.8	-
252	" "	5	4.0	
197	" "	0	----	0
203	" "	0	----	0
207	" "	1	5.0	1
145	" "	0	----	0
263	" "	3	6.3	1
151	" "	5	4.6	-
164	" "	0	----	3
166	" "	2	8.0	2
167	" "	5	5.0	
171	" "	4	4.2	1
199	" "	0	----	0
205	" "	3	6.3	0
227	P. richardiae	0	----	0
206	P. drechsleri	0	----	3

P. cactorum is usually weakly or non-pathogenic, yet one isolation (No. 168) killed all inoculated plants, but the average of 11 days which elapsed between inoculation and death indicates the slow spread of the infections.

Of 3 isolations of *P. nicotianae* each fell into a different group, but *P. cinnamomi* (5 isolations), *P. citrophthora* (3 isolations) and *P. meadii* (3 isolations) were uniformly non-pathogenic.

The typical isolations of *P. palmivora* are more frequently virulently pathogenic than the atypical ones, but further examination of the facts indicates that the apparent difference in virulence is probably associated with the origins of the cultures rather than their typical or atypical character. There are 4 typical cultures from rubber and cacao (Nos. 14, 4, 5 and 7) all of which proved non-pathogenic. Among the atypical cultures there are 13 from rubber and cacao (Nos. 102, 116, 140, 18, 22, 26, 36, 44, 100, 121, 6, 130 and 141) and none of these were virulently pathogenic. The weak infecting power of isolations from cacao and rubber is probably more evidence of the occurrence of physiologically differentiated forms.

Selectivity of hosts is further supported by the virulence of Nos. 13, 127 and 137, which were isolated from papaw, the first in Ceylon, the others in the Philippines. Other markedly virulent isolations are Nos. 123 and 236 (from Borassus), No. 271 (from Antirrhinum in Porto Rico), Nos. 249 and 250 (from Citrus seedlings in Porto Rico, and No. 146 (from Sabal in Porto Rico). Among the atypical cultures Nos. 254 and 255 (from orchids in Java) are notably virulent, as shown by the rapidity of invasion and the numbers of seedlings killed. Another isolation from an orchid in Ceylon (No. 16) killed 4 plants but invaded the stems very slowly.

In connection with the fact that *P. palmivora* from rubber proved non-pathogenic it is noteworthy that *P. meadii* (2 isolations of which are from rubber) also failed to infect.

P. parasitica exhibits its usual diversity. Sixteen of 57 isolations were virulently pathogenic and 26 were non-pathogenic. In this species there are no very marked correlations between the original hosts of the isolations and their ability to infect papaw seedlings.

Few experimental inoculations of papaw stems have been reported. *P. palmivora* was reported pathogenic to bark by Hartley (93), who used an isolation from cacao in Java; Ocfemia and Roldan (146) found an isolation from blighted Citrus seedlings in the Philippines pathogenic to papaw seedlings; the writer (227) reported Sabal and coconut isolations in Porto Rico pathogenic. *P. cinnamomi* was reported non-pathogenic by Rands (173).

Tomato seedlings.—Tomato seedlings were wounded and inoculated about one-half inch above the surface of the soil. The ability of the isolations to cause rotting is greatest when the plants are young and, in most cases, decreases rapidly as the age and hardness of the tissues increase. In very young seedlings the typical injury is a soft wet rot very similar to the usual damping off. On older plants pathogenic isolations cause a brown sunken lesion which may kill the plants by weakening the stems and allowing them to fall over (Fig. 20). Sometimes such fallen plants are able to live for considerable periods, and the hyphae apparently do not invade and plug up the vascular cavities. Collapse of the stems is, however, usually followed very soon by wilting and death. The results of the inoculations appear in Table 18.

The isolations may be grouped as follows:

Virulently pathogenic	Weakly pathogenic	Non-pathogenic
P. capsici	*P. boehmeriae*	*P. arecae*
P. cryptogea	*P. cactorum* (3)	*P. cactorum* (12)
P. hydrophila	*P. mexicana*	*P. cambivora*
P. palmivora (typ.) (7)	*P. nicotianae* (1)	*P. cinnamomi*
P. palmivora (atyp.) (1)	*P. palmivora* (typ.) (10)	*P. citricola*
P. parasitica (27)	*P. palmivora* (atyp.) (12)	*P. citrophthora*
P. drechsleri	*P. parasitica* (16)	*P. colocasiae*
		P. erythroseptica
		P. meadii
		P. nicotianae (2)
		P. palmivora (typ.) (5)
		P. palmivora (atyp.) (8)
		P. parasitica (14)
		P. richardiae

Isolations of *P. cactorum* and *P. nicotianae* proved weakly to non-pathogenic. Of the typical cultures of *P. palmivora* which attacked seedlings vigorously one is from breadfruit, two from papaw, one from Citrus, one from Dendrobium, one from cotton and one from rubber. The only virulent atypical culture was one from cacao. A majority of the isolations of the species (35 of 43) were weakly to non-pathogenic, and the virulence of isolations is not definitely associated with certain original hosts.

P. parasitica is more frequently and more virulently pathogenic than *P. palmivora*, 27 of 57 isolations proving virulent. All isolations from pepper (Capsicum), cotton and tomato attacked tomatoes rather severely, while all from Bryophyllum, Catharanthus, Citrus, and rhubarb were non-pathogenic or caused slight infections. Isolations from the following hosts varied as to pathogenicity: Hibiscus (1 of 3 virulent),

TABLE 18.—RESULTS OF INOCULATIONS OF WOUNDED STEMS OF MARGLOBE TOMATO (LYCOPERSICON LYCOPERSICON (L.) KARST.) SEEDLINGS 4 TO 9 INCHES TALL AT MAYAGUEZ, P. R. AUG., 1927, SEPT., 1928, AND JULY, 1929
(Five Seedlings Were Inoculated With Each Isolation)

No.	Species	No. killed during 20 days	Av. no. of days from inoculation to death	No. with canker at wound after 20 days
153	P. arecae	0	----	0
266	P. boehmeriae	1	7.0	0
192	P. cactorum	0	----	0
194	" "	0	----	0
179	" "	0	----	2
184	" "	0	----	1
189	" "	0	----	1
193	" "	0	----	0
168	" "	0	----	0
172	" "	1	6.0	3
200	" "	2	11.0	0
210	" "	0	----	0
243	" "	0	----	0
190	" "	0	----	0
149	" "	0	----	0
160	" "	0	----	0
196	" "	0	----	0
198	P. cambivora	0	----	0
208	"	0	----	0
147	P. capsici	5	3.0	-
253	" "	5	6.4	-
173	P. cinnamomi	0	----	0
174	" "	0	----	0
195	" "	0	----	0
242	" "	0	----	0
244	" "	0	----	0
267	P. citricola	0	----	0
154	P. citrophthora	0	----	0
221	" "	0	----	0
222	" "	0	----	0
152	P. colocasiae	0	----	0
239	" "	0	----	0
150	P. cryptogea	3	2.7	2
176	P. erythroseptica	0	----	0
241	P. hydrophila	5	3.0	-
223	P. meadii	0	----	0
238	" "	0	----	1
257	" "	0	----	0
148	P. mexicana	2	6.0	3
216	P. nicotianae	0	----	0
232	" "	0	----	0
247	" "	0	----	3
271	P. palmivora (typ.)	1	5.0	0
12	" "	3	6.7	1
123	" "	1	2.0	4
236	" "	0	----	1
13	" "	0	----	0
127	" "	5	4.0	-
137	" "	3	4.0	2
249	" "	0	----	3
250	" "	1	8.0	2
265	" "	5	2.0	-
1	" "	1	2.0	2
3	" "	2	4.5	1
17	" "	0	----	0
16	" "	2	2.5	3
9	" "	4	4.0	1
14	" "	2	2.0	3
272	" "	0	----	0
235	" "	0	----	0
146	" "	2	3.5	2
4	" "	2	3.0	2
5	" "	1	2.0	2
7	" "	1	2.0	1
255	P. palmivora (atyp)	0	----	0
180	" "	0	----	0
126	" "	0	----	2
136	" "	0	----	0
97	" "	0	----	3
102	" "	1	3.0	2
116	" "	0	----	0
140	" "	2	4.0	1
15	" "	0	----	3

TABLE 18.—(CONTINUED)

No.	Species	No. killed during 20 days	Av. no. of days from inoculation to death	No. with canker at wound after 20 days
138	" "	1	2.0	4
18	" "	0	----	0
22	" "	1	4.0	0
26	" "	1	5.0	0
36	" "	1	5.0	4
44	" "	1	3.0	2
100	" "	0	---	0
121	" "	0	----	0
6	" "	0	----	0
130	" "	4	2.2	1
141	" "	2	7.0	2
254	" "	1	4.0	0
185	P. parasitica	0	----	0
228	" "	0	----	0
268	" "	0	---	2
183	" "	3	2.7	2
209	" "	2	2.0	3
260	" "	0	----	0
269	" "	0	---	4
144	" "	0	----	0
178	" "	1	4.0	2
2	" "	0	---	2
8	" "	3	2.3	2
10	" "	5	3.0	-
11	" "	5	2.0	-
258	" "	0	---	1
142	" "	0	----	0
261	" "	0	----	1
262	" "	5	2.0	-
165	" "	4	4.0	1
211	" "	3	4.0	1
212	" "	1	7.0	2
270	" "	4	5.0	1
132	" "	4	3.0	1
162	" "	5	2.4	-
177	" "	3	3.7	2
181	" "	2	5.0	3
186	" "	5	3.6	-
187	" "	5	2.6	-
191	" "	5	5.0	-
251	" "	3	3.3	1
264	" "	4	2.0	0
143	" "	0	----	0
217	" "	0	---	0
259	" "	4	4.0	0
159	" "	0	----	0
169	" "	0	----	2
175	" "	0	----	0
204	" "	0	----	0
234	" "	0	----	1
139	" "	5	2.6	-
161	" "	5	4.0	-
182	" "	2	3.5	3
201	" "	3	3.3	1
202	" "	0	----	2
213	" "	4	4.8	0
252	" "	2	5.5	1
197	" "	0	----	1
203	" "	2	6.0	0
207	" "	5	3.4	-
145	" "	1	13.0	1
263	" "	4	2.2	0
151	" "	5	2.0	-
164	" "	1	7.0	0
166	" "	5	2.6	-
167	" "	5	3.6	-
171	" "	1	5.0	2
199	" "	2	7.0	2
205	" "	1	5.0	0
227	P. richardiae	0	----	0
206	P. drechsleri	5	2.2	-

Lilium spp. (3 of 4 virulent), eggplant (5 of 7 virulent), potato (1 of 3 virulent). Of 13 isolations from Solanaceae other than the tomato 8 were virulent and 5 weakly to non-pathogenic.

The above observations indicate some degree of specialization, but there are probably no definite, fixed relationships of hosts and physiological races within the fungous species comparable to those known in *Puccinia graminis* and *Colletotrichum gloeosporioides*.

P. arecae was reported pathogenic to very young seedlings, but non-pathogenic to older ones by Dastur (52).

P. cactorum was found non-pathogenic by DeBary (58). Cooper and Porter (48), reported similar results with their *P. paeoniae*, and Sundararaman and Ramakrishnan (209) could not infect seedlings with their *P. pini var. antirrhini*.

Fig. 20.—Tomato plants photographed 3 days after inoculation near the soil level with *P. capsici* (*P. hydrophila*) (No. 241) at left and *P. parasitica* (No. 187) at right.

P. cryptogea proved pathogenic in inoculations by Pethybridge and Lafferty (162), and Brittlebank and Fish (25); the latter reported that the fungus caused death in 5 days.

P. hydrophila was reported pathogenic by Curzi (49).

P. meadii was found unable to infect seedlings by Dastur (53) and Sharples, Norris and others (194).

P. nicotianae was reported non-pathogenic by Tisdale (221), but Tisdale and Kelley (225) later obtained very slight infections; Palm (150)

obtained infections and Palm and Jochems (151) later reported that the fungus was very weakly pathogenic, a saturated atmosphere during the 24 hours following inoculation proving necessary for infection; Nolla (144) obtained a damping off of very young seedlings.

P. palmivora isolated from Hevea failed to infect seedlings, according to Thompson (219).

P. parasitica caused wilting of plants 4-6 inches tall in Dastur's (52) (54) experiments. Tisdale and Kelley (225) found *P. parasitica* more virulent than *P. nicotianae*. Clara (40) using an isolation from *Sandoricum Koetjape*, probably *P. parasitica*, reported very slight damping off of seedlings. Williams (234) reported negative results with a cucumber isolation, probably *P. parasitica*.

P. thalictri failed to infect young leaves according to Clinton (43).

P. infestans has often been used for inoculating tomato foliage. Isolations from potato were reported by some investigators to be unable to infect tomatoes. Other obtained only slight infections. Isolations from tomatoes sometimes proved less virulent to potatoes than isolations from that host. Evidences of biologic specialization in *P. infestans* appear in the results reported by Farlow (70), Wiltshire (239), Giddings and Berg (85), Siemaszko (198) and Berg (16). Another group observed no differences in the virulence of strains from the two hosts and considered them equally capable of infecting both: McAlpine (129), Reed (175), Salmon and Wormald (188), Marchal and Foex (125) and Bondartzeva-Monteverde (22). Melhus (136) obtained leaf infections readily on tomatoes with a potato isolation, but unwounded fruits were not attacked.

Eggplant seedlings.—The stems of eggplant seedlings were wounded and inoculated about midway between the base and tip. Infection caused dark, sunken areas and resulted in death when the invaded region girdled the stem (Fig. 21).

The isolations may be grouped according to their pathogenicity:

Virulently pathogenic	Weakly pathogenic	Non-pathogenic
P. capsici (1)	*P. cactorum* (1)	*P. arecae*
P. hydrophila	*P. capsici* (1)	*P. boehmeriae*
P. mexicana	*P. citrophthora*	*P. cactorum* (14)
P. nicotianae	*P. meadii* (1)	*P. cambivora*
P. palmivora (atyp.) (3)	*P. palmivora* (typ.) (11)	*P. cinnamomi*
P. parasitica (18)	*P. palmivora* (atyp.) (6)	*P. citricola*
	P. parasitica (22)	*P. colocasiae*
	P. drechsleri	*P. cryptogea*
		P. erythroseptica
		P. meadii (2)
		P. palmivora (typ.) (11)
		P. palmivora (atyp.) (12)
		P. parasitica (17)
		P. richardiae

TABLE 19.—RESULTS OF INOCULATIONS OF WOUNDED EGGPLANT (SOLANUM MELONGENA L.) SEEDLINGS 3 TO 8 INCHES TALL IN JUNE, 1926, AUG., 1927, OCT., 1928, AND JULY, 1929 AT MAYAGUEZ, P. R.

No.	Species	No. inoculated	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
153	P. arecae	5	0	---	0
266	P. boehmeriae	5	0	---	0
192	P. cactorum	5	0	---	0
194	" "	5	0	---	0
179	" "	5	0	---	0
184	" "	5	0	---	0
189	" "	5	0	---	0
193	" "	5	0	---	0
168	" "	5	0	---	0
172	" "	5	0	---	0
200	" "	5	0	---	0
210	" "	5	0	---	0
190	" "	5	0	---	0
243	" "	5	0	---	0
149	" "	5	0	---	0
160	" "	5	0	---	2
196	" "	5	0	---	0
198	P. cambivora	5	0	---	0
208	" "	5	0	---	0
147	P. capsici	5	4	2.5	1
253	" "	5	0	---	5
173	P. cinnamomi	5	0	---	0
174	" "	5	0	---	0
195	" "	5	0	---	0
242	" "	5	0	---	0
244	" "	5	0	---	0
267	P. citricola	5	0	---	0
154	P. citrophthora	5	1	2.0	1
221	" "	5	1	2.0	1
222	" "	5	3	9.0	1
152	P. colocasiae	5	0	---	0
239	" "	5	0	---	0
150	P. cryptogea	5	0	---	0
176	P. erythroseptica	5	0	---	0
241	P. hydrophila	5	5	3.2	-
223	P. meadii	5	2	4.0	0
238	" "	5	0	---	0
257	" "	5	0	---	0
148	P. mexicana	5	5	3.0	-
216	P. nicotianae	5	2	2.5	3
232	" "	5	5	3.4	-
247	" "	5	4	7.0	1
271	P. palmivora (typ.)	5	0	---	0
12	" "	5	1	12.0	2
123	" "	10	1	4.0	1
236	" "	5	0	---	0
13	" "	10	1	5.0	0
127	" "	10	2	3.0	3
137	" "	10	2	4.0	2
249	" "	5	1	14.0	3
250	" "	5	0	---	2
265	" "	5	0	---	0
1	" "	10	0	---	0
3	" "	10	1	4.0	2
17	" "	10	0	---	0
16	" "	10	0	---	1
9	" "	10	3	17.0	2
14	" "	5	0	---	1
272	" "	5	0	---	0
235	" "	5	1	5.0	3
146	" "	10	0	---	1
4	" "	10	1	9.0	0
5	" "	10	0	---	0
7	" "	10	0	---	0
255	P. palmivora (atyp.)	5	0	---	0
180	" "	5	0	---	3
126	" "	10	0	---	0
136	" "	10	0	---	0
97	" "	10	0	---	0
102	" "	10	6	5.5	2

TABLE 19.—(CONTINUED)

No.	Species	No. inoculated	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
116	" "	5	0	---	0
140	" "	10	2	6.5	1
15	" "	10	0	---	0
138	" "	10	0	---	0
18	" "	10	2	5.0	0
22	" "	10	6	4.5	1
26	" "	10	1	2.0	0
36	" "	10	0	---	0
44	" "	10	1	7.0	2
100	" "	10	6	6.7	1
121	" "	10	0	---	0
6	" "	10	0	---	0
130	" "	10	4	3.0	0
141	" "	10	0	---	0
254	" "	5	0	---	0
185	P. parasitica	5	0	---	0
228	" "	5	0	---	0
268	" "	5	0	---	0
183	" "	5	1	5.0	2
209	" "	5	0	---	1
260	" "	5	1	5.0	0
269	" "	5	1	10.0	0
144	" "	10	0	---	0
178	" "	5	1	2.0	1
2	" "	10	0	---	2
8	" "	5	5	3.0	-
10	" "	5	3	6.3	1
11	" "	10	10	3.6	-
258	" "	5	0	---	2
142	" "	10	0	---	0
261	" "	5	2	5.0	3
262	" "	5	1	8.0	1
165	" "	5	1	2.0	4
211	" "	5	5	2.0	-
212	" "	5	5	3.8	-
270	" "	5	5	4.6	-
132	" "	10	0	---	0
162	" "	5	2	13.5	3
177	" "	5	1	2.0	4
181	" "	5	2	6.0	1
186	" "	5	0	---	1
187	" "	5	2	12.0	2
191	" "	5	3	3.0	0
251	" "	5	0	---	4
264	" "	5	0	---	0
143	" "	10	2	5.0	0
217	" "	5	0	---	3
259	" "	5	1	5.0	0
159	" "	5	0	---	0
169	" "	5	0	---	0
175	" "	5	3	4.3	1
204	" "	5	2	4.0	0
234	" "	5	1	5.0	3
139	" "	10	5	3.6	2
161	" "	5	0	---	1
182	" "	5	0	---	3
201	" "	5	4	4.0	1
202	" "	5	2	4.0	3
213	" "	5	5	2.2	-
252	" "	5	0	---	3
197	" "	5	0	---	0
203	" "	5	0	---	0
207	" "	5	5	3.4	-
145	" "	10	2	3.0	3
263	" "	5	1	7.0	3
151	" "	5	4	3.0	0
164	" "	5	2	6.5	3
166	" "	5	0	---	2
167	" "	5	0	---	0
171	" "	5	0	---	0
199	" "	5	1	3.0	3
205	" "	5	5	2.0	-
227	P. richardiae	5	0	---	0
206	P. drechsleri	5	1	2.0	2

No isolations of *P. cactorum* killed wounded seedlings. One caused slight infection at the wound in two plants.

P. hydrophila, *P. mexicana*, and *P. nicotianae* proved virulently pathogenic. *P. palmivora* is usually weakly to non-pathogenic, only 3 isolations proving markedly virulent, Nos. 102, 22 and 100. These 3 are from rubber and cacao in Java.

P. parasitica exhibited virulent pathogenicity in 18 of 57 isolations, distributed as to origins as follows: Cotton, all 3 isolations; Hibiscus, 1 of 3 isolations; Lilium spp., 3 of 4 isolations; tomato, 2 of 8

Fig. 21.—Eggplant seedlings photographed 4 days after inoculation above the lowest leaf with *P. parasitica* (No. 201, 2 plants on left) and *P. capsici* (No. 147, 2 plants on right).

isolations; rhubarb, 1 of 4 isolations; eggplant, 4 of 7 isolations; and potato, 1 of 3 isolations. There appears to be little correlation between the original host and ability to infect eggplant seedlings.

P. arecae was reported pathogenic to plants 1-2 in. tall by Coleman (46), but non-pathogenic to seedlings 4-6 in. tall.

P. cactorum (*P. pini var. antirrhini*) failed to infect seedlings, according to Sundararaman and Ramakrishnan (209).

P. citricola was found non-pathogenic by Sawada (189).

P. meadii was found non-pathogenic by Dastur (53) and Sharples, Norris and others (194).

P. nicotianae did not attack stems in experiments by Tisdale and Kelley (225), but Nolla (144) reported positive results.

P. parasitica was found pathogenic to plants 4-6 in. tall by Dastur (52) and Clara (40) reported a slight damping off of seedlings inoculated with a fungus, probably *P. parasitica*, from *Sandoricum Koetjape*.

Cacao seedlings.—Cacao seedlings were wounded and inoculated about 2 inches above the base. Infections caused a brown, slightly sunken area about the wound. In severe infections the leaves drooped and became dry (Fig. 22). Stem infections caused a browning of the cortex similar to the condition occurring in cankers on mature trees.

Fig. 22.—Cacao seedlings. 1. Inoculated with *P. palmivora* (No. 4, from cacao). 2. Inoculated with *P. palmivora* (No. 1, from coconut). 3. Checks. Photographed 7 days after inoculation.

P. arecae, *P. cactorum*, *P. cambivora*, *P. cinnamomi*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. erythroseptica*, *P. mexicana*, *P. richardiae*, and *P. drechsleri* failed to infect the stems.

P. capsici infected 9 of 15 inoculated plants and killed 3 of them; *P. hydrophila* invaded 2 of 5 but caused lesions only; *P. meadii* attacked but did not kill the seedlings, and all 3 isolations may be considered weakly pathogenic; one isolation of *P. nicotianae* attacked 2 of 5 plants, destroying one.

Of the isolations of *P. palmivora* Nos. 4, 5, 7, 22, 36, 44, 100 and 141, all from cacao, proved virulently pathogenic. Nos. 236 (Borassus), 102 (Hevea), 18, 26, 121, 130 (cacao) were slightly pathogenic, and all others were non-pathogenic. These results indicate very clearly a specialization of the strains of *P. palmivora*, at least in regard to their

TABLE 20.—RESULTS OF INOCULATIONS OF WOUNDED CACAO (THEOBROMA CACAO L.) SEEDLINGS 6 TO 12 INCHES TALL IN JAN. AND APR. 1926, AUG. AND NOV., 1927, AND JULY, 1928, AT MAYAGUEZ, P. R.

No.	Species	No. inoculated	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
153	P. arecae	5	0		0
192	P. cactorum	5	0	---	0
194	" "	5	0	--	0
179	" "	5	0	---	0
184	" "	5	0	-	0
189	" "	5	0	---	0
193	" "	5	0	- -	0
168	" "	5	0	--	0
172	" "	5	0	---	0
200	" "	5	0	---	0
210	" "	5	0	---	0
190	" "	5	0	---	0
243	" "	5	0	- -	0
149	" "	5	0	- -	0
160	" "	5	0	---	0
196	" "	5	0	---	0
198	P. cambivora	5	0	---	0
208	" "	5	0	---	0
147	P. capsici	10	2	7.0	3
253	" "	5	1	7.0	3
173	P. cinnamomi	5	0	---	0
174	" "	5	0	- -	0
195	" "	5	0	---	0
242	" "	5	0	---	0
244	" "	5	0	---	0
154	P. citrophthora	5	0	--	0
221	" "	5	0	- -	0
222	" "	5	0	---	0
152	P. colocasiae	5	0	---	0
239	" "	5	0	---	0
150	P. cryptogea	5	0	---	0
176	P. erythroseptica	5	0	---	2
241	P. hydrophila	5	0	---	2
223	P. meadii	10	0	---	3
238	" "	5	0	- -	5
257	" "	5	0	---	2
148	P. mexicana	10	0	---	0
216	P. nicotianae	5	0	---	0
232	" "	5	1	7.0	1
247	" "	5	0	-	1
12	P. palmivora (typ.)	10	0	-	0
123	" "	10	0	-	0
236	" "	5	0	--	2
13	" "	10	0	---	0
127	" "	10	0	- -	0
137	" "	10	0	---	0
249	" "	5	0	- -	1
250	" "	5	0	- -	0
265	" "	5	0	-	0
1	" "	10	0	---	0
3	" "	10	0	---	0
17	" "	10	0	---	0
16	" "	10	0	---	0
9	" "	10	0	- -	0
14	" "	10	0	--	0
235	" "	5	0	-	1
146	" "	5	0	-	0
4	" "	18	14	6.2	4
5	" "	10	6	6.7	4
7	" "	15	7	7.4	3
255	P. palmivora (atyp.)	5	0	-	0
180	" "	5	0	-	0
126	" "	10	0	- -	0
136	" "	10	0	-	0
97	" "	10	0	-	0
102	" "	10	1	12.0	6
116	" "	10	0	-	0
140	" "	10	0	-	0
15	" "	10	0	-	0
138	" "	10	0	-	0
18	" "	10	3	9.3	3
22	" "	10	4	5.2	4
26	" "	15	1	7.0	0
36	" "	15	6	7.3	7

TABLE 20.—(CONTINUED)

No.	Species	No. inoculated	No. killed during 30 days	Av. no. of days from inoculation to death	No. with canker at wound after 30 days
44	" "	10	5	5.2	5
100	" "	15	10	7.8	5
121	" "	15	3	7.0	0
6	" "	13	0	---	0
130	" "	10	2	12.0	2
141	" "	10	4	5.5	4
254	" "	5	0	---	0
185	P. parasitica	5	0	---	0
228	" "	5	0	---	0
183	" "	5	0	---	0
209	" "	5	0	---	0
260	" "	5	0	---	0
144	" "	10	0	---	0
178	" "	5	0	---	0
2	" "	10	0	---	0
8	" "	10	4	7.5	2
10	" "	15	2	13.0	9
11	" "	10	0	---	2
258	" "	5	0	---	0
142	" "	10	0	---	0
261	" "	5	0	---	0
262	" "	5	0	---	0
165	" "	5	0	---	0
211	" "	5	0	---	0
212	" "	10	1	7.0	2
132	" "	10	0	---	0
162	" "	5	0	---	0
177	" "	5	0	---	0
181	" "	5	0	---	0
186	" "	5	0	---	0
187	" "	5	0	---	0
191	" "	5	0	---	0
251	" "	5	0	---	0
264	" "	5	0	---	0
143	" "	10	0	---	0
217	" "	5	0	---	0
259	" "	5	0	---	0
159	" "	5	0	---	0
169	" "	5	0	---	0
175	" "	5	0	---	0
204	" "	5	0	---	0
234	" "	5	0	---	2
139	" "	10	0	---	0
161	" "	5	0	---	0
182	" "	5	0	---	0
201	" "	5	0	---	0
202	" "	5	0	---	0
213	" "	5	0	---	0
252	" "	5	0	---	0
197	" "	5	0	---	0
203	" "	5	0	---	0
207	" "	5	0	---	0
145	" "	10	0	---	0
263	" "	5	0	---	0
151	" "	5	0	---	0
164	" "	5	0	---	0
166	" "	5	0	---	0
167	" "	5	0	---	0
171	" "	5	0	---	0
199	" "	5	0	---	0
205	" "	5	0	---	0
227	P. richardiae	5	0	---	0
206	P. drechsleri	5	0	---	0

ability to infect cacao; only one isolation from cacao (No. 6) failed to infect stems and also fruits. The pathogenicity of the Borassus isolation (No. 236) was very weak, causing slight bark infections on 2 of 5 inoculated plants, but No. 102, from Hevea was definitely pathogenic, invading 7 of 10 plants and causing the death of one.

Of the isolations of *P. parasitica* three (Nos. 8, 10, and 212) killed one or more of 10 inoculated plants. No. 234 caused lesions on 2 of 5 plants and all others proved even less virulent. These results agree with those of cacao fruit inoculations in that they indicate that *P. parasitica* may occasionally invade cacao, probably through wounds and cause a diseased condition which cannot be distinguished from the symptoms caused by *P. palmivora*. None of the four isolations of *P. parasitica* approached, in virulence, the most virulent isolations of *P. palmivora*.

Rutgers (185) failed to infect wounded stems with *P. cactorum*, *P. colocasiae*, *P. parasitica* (*P. jatrophae*), and *P. nicotianae*.

P. meadii was reported non-pathogenic to seedlings by Dastur (53) and Sharples, Norris and others (194).

Isolations of *P. palmivora* from nutmeg and cacao in Java proved pathogenic, according to Rutgers (185); the writer (227) found isolations from Sabal and the coconut non-pathogenic.

Tender grapefruit stems.—Young stems on grapefruit trees 2-4 ft. tall were wounded and inoculated. The inoculations were made as a new flush of growth was starting and the stems used were green and succulent. The wounds were made about one inch below the growing point. The more virulent isolations invaded the shoots rapidly and caused a browning of the apical portions extending 3 to 6 in. down the stem. Less virulent isolations caused dark lesions, frequently accompanied by gum exudations, at the wound. The lesions usually caused the twigs to become bent and distorted.

The following groups are based on the results of the inoculations:

Virulently pathogenic	Weakly pathogenic	Non-pathogenic
P. citrophthora	*P. meadii*	*P. arecae*
P. palmivora (typ.) (5)	*P. nicotianae* (2)	*P. boehmeriae*
P. palmivora (atyp.) (1)	*P. palmivora* (typ.) (9)	*P. cactorum*
P. parasitica (11)	*P. palmivora* (atyp.) (9)	*P. cambivora*
	P. parasitica (35)	*P. capsici*
		P. cinnamomi
		P. citricola
		P. colocasiae
		P. cryptogea
		P. erythroseptica
		P. hydrophila
		P. mexicana
		P. nicotianae (1)
		P. palmivora (typ.) (8)
		P. palmivora (atyp.) (11)
		P. parasitica (11)
		P. richardiae
		P. drechsleri

TABLE 21.—RESULTS OF INOCULATIONS OF WOUNDED YOUNG SHOOTS ON YOUNG GRAPEFRUIT (CITRUS PARADISI MACF.) TREES AT MAYAGUEZ, P. R., JUNE, 1929
(Five Shoots Were Inoculated With Each Isolation)

No.	Species	No. killed back after 10 days	No. with lesions at wounded point after 10 days	Type of lesions
153	P. arecae	0	0	
266	P. boehmeriae	0	1	slight
192	P. cactorum	0	0	
194	" "	0	0	
179	" "	0	0	
184	" "	0	0	
189	" "	0	0	
193	" "	0	0	
168	" "	0	0	
172	" "	0	0	
200	" "	0	0	
210	" "	0	0	
190	" "	0	0	
243	" "	0	0	
149	" "	0	0	
160	" "	0	0	
196	" "	0	0	
198	P. cambivora	0	0	
147	P. capsici	0	0	
253	" "	0	1	slight
173	P. cinnamomi	0	0	
174	" "	0	0	
195	" "	0	0	
242	" "	0	0	
244	" "	0	0	
267	P. citricola	0	1	slight
154	P. citrophthora	5	-	
221	" "	5		
222	" "	3	2	severe
152	P. colocasiae	0	0	
239	" "	0	0	
150	P. cryptogea	0	0	
176	P. erythroseptica	0	0	
241	P. hydrophila	0	1	slight
223	P. meadii	0	2	slight
238	" "	0	5	moderate
257	" "	1	4	severe
148	P. mexicana	0	0	
216	P. nicotianae	0	0	
232	" "	0	5	slight
247	" "	0	2	slight
271	P. palmivora (typ.)	0	5	severe
12	" "	0	0	
123	" "	0	0	
236	" "	0	2	slight
13	" "	0	2	slight
127	" "	0	4	slight
137	" "	0	3	moderate
249	" "	5	-	
250	" "	5	-	
265	" "	5	-	
1	" "	0	0	
3	" "	5	-	
17	" "	0	0	
16	" "	0	2	slight
9	" "	4	1	severe
14	" "	1	4	moderate
272	" "	0	2	slight
235	" "	0	0	
146	" "	0	4	moderate
4	" "	0	0	
5	" "	0	0	
7	" "	0	1	slight
255	P. palmivora (atyp.)	1	3	moderate
180	" "	0	5	severe
126	" "	0	1	severe
136	" "	0	0	
97	" "	5	-	
102	" "	1	2	moderate
116	" "	0	0	
140	" "	0	4	severe
15	" "	0	1	severe
138	" "	0	0	

TABLE 21. (CONTINUED)

No.	Species	No. killed back after 10 days	No. with lesions at wounded point after 19 days	Type of lesions
18	" "	1	3	slight
22	" "	0	4	moderate
26	" "	0	0	
36	" "	0	1	slight
44	" "	0	1	slight
100	" "	0	1	slight
121	" "	0	3	moderate
6	" "	0	0	
130	" "	0	2	slight
141	" "	1	4	moderate
254	" "	0	0	
185	P. paraselene	0	0	
228	" "	0	0	
268	" "	0	2	slight
183	" "	0	4	moderate
209	" "	0	5	moderate
260	" "	0	2	slight
269	" "	0	1	slight
144	" "	0	4	severe
178	" "	0	4	moderate
2	" "	0	3	slight
8	" "	2	5	severe
10	" "	0	1	slight
11	" "	0	4	slight
258	" "	0	2	slight
147	" "	0	0	
264	" "	5	2	severe
262	" "	0	5	severe
165	" "	0	1	slight
211	" "	2	3	moderate
212	" "	0	1	slight
270	" "	0	4	severe
132	" "	2	5	severe
162	" "	0	2	slight
177	" "	0	5	moderate
181	" "	3	2	moderate
186	" "	0	1	slight
187	" "	0	4	moderate
191	" "	0	4	moderate
251	" "	5	2	severe
264	" "	1	5	severe
143	" "	0	4	slight
217	" "	0	0	
259	" "	2	1	severe
159	" "	0	0	
169	" "	0	4	moderate
175	" "	0	1	slight
204	" "	0	0	
234	" "	0	4	moderate
139	" "	0	1	slight
161	" "	4	1	severe
182	" "	0	5	moderate
201	" "	0	2	slight
202	" "	5		
213	" "	0	3	slight
252	" "	0	3	slight
197	" "	0	4	slight
203	" "	0	4	moderate
207	" "	3	2	severe
145	" "	3	2	severe
263	" "	2	3	severe
151	" "	2	2	slight
164	" "	0	4	severe
166	" "	1	4	severe
167	" "	0	2	slight
171	" "	1	3	severe
199	" "	0	0	
205	" "	0	3	slight
227	P. richardsi	0	0	
206	P. drechsleri	0	1	slight

The isolations of *P. terrestrica* caused a severe die back of infected stems.

One isolation of *P. nicotianae* was non pathogenic and 2 weakly virulent. All isolations of *P. meadii* were weakly pathogenic.

P. palmivora was usually weakly to non pathogenic. Six isolations however, were very virulent, Nos. 245, 250 and 265 (Citrus), No. 3, (coconut), No. 9, (cotton), and No. 97 (Erythrina) caused a severe die back in almost all inoculations. The virulence of 3 Citrus isolations offer further evidence of the existence of specialized strains in *P. palmivora*.

P. parasitica resembles *P. palmivora* in the pathogenicity of most isolations, 16 of 57 failing to infect or causing rather slight infections. Eleven isolations showed moderate infecting power, but only 2 rivalled the virulent isolations of *P. palmivora*. These are Nos. 161 and 202, both from eggplant and received from Drechsler. Two isolations from Citrus (Nos. 144 and 178) caused lesions but failed to kill the stems.

Tobacco plants.—The stems of White Burley plants 3 to 8 inches tall were wounded and inoculated near the base, just above the soil. All isolations except those of *P. infestans*, *P. hibernalis* and *P. syringae* were used for inoculations at Mayaguez, P. R., in July, 1927, Sept. and Oct., 1928 and June and July, 1929. Five plants were inoculated with each.

Nos. 216, 232 and 247, isolated from tobacco in Florida, Porto Rico, and Sumatra, respectively, proved pathogenic and caused typical symptoms of black shank. No. 216 killed all inoculated plants after an average of 14 days. No. 232 also killed all the plants after an average of 14 days. No. 247 proved somewhat less virulent, killing 3 of 5 inoculated plants after 23, 23, and 27 days. Attacked plants became dark in color at the wound and the infected areas spread upward and downward. The more virulent isolations finally invaded the entire stem (Fig. 23).

No other isolations caused the death of a plant. Occasionally a slight lesion appeared at the wound but did not increase in size or cause any apparent effect on growth. The final examination was made 30 days after inoculation.

P. nicotianae (Nos. 216, 232 and 247) is morphologically indistinguishable from *P. parasitica*. Inoculations of hosts other than tobacco with both species reveal no marked differences, yet *P. nicotianae* is capable of producing black shank in tobacco while 57 isolations of *P. parasitica* are non pathogenic. The definite difference in pathogenicity may be used to distinguish *P. nicotianae*, which will later be considered a variety of *P. parasitica*.

Since *P. parasitica* has been isolated from young plants, inoculations were made on 5 small plants with 2 well developed foliar leaves. The stems were wounded at the point of attachment of the leaves.

All isolations of *P. nicotianae* killed all very young inoculated plants within 2 days. The following isolations of *P. parasitica* killed one to three plants within 5 days: Nos. 8, 11, 142, 165, 212, 162, 181, 187,

Fig. 23.—Tobacco plants inoculated with *P. parasitica var. nicotianae* (No. 247). Left, stem cut to show the discoloration of the vascular region. Right, external appearance. Photographed 23 days after inoculation. The leaf spots are caused by *Cercospora sp.*

161, 182, 203, and 199. *P. nicotianae* spread rapidly through the stem tissues and leaf bases. The pathogenic isolations of *P. parasitica* caused a local soft wet rot and showed no tendency to grow through the stems vertically. The type of injury caused was similar to damping-off. It is

probably true that *P. parasitica* may cause a disease of young seedlings, and yet be incapable of invading more mature plants. *P. nicotianae*, however, is able to infect and kill plants in any stage of growth.

P. cactorum, *P. citrophthora*, *P. mexicana*, and *P. palmivora* occasionally caused the death of a very young wounded seedling. None of these species infected older plants.

The reports of attempts to infect tobacco with isolations from other plants are nearly always negative. *P. cactorum* was reported non-pathogenic by Rutgers (185), and Sundararaman and Ramakrishnan (209) obtained no infections with *P. pini var. antirrhini*.

P. citricola failed to infect seedlings, according to Sawada (189).

P. colocasiae proved non pathogenic in stem and leaf inoculations, according to Jensen (102) (103), and Rutgers (185).

P. palmivora failed to infect stems or leaves in experiments by Rutgers (185) and Thompson (219).

P. parasitica proved unable to infect tobacco, according to Dastur (52), Tisdale (221), Tisdale and Kelley (225) and Nolla (144). Jensen (103) and Rutgers (185) reported *P. jatrophae* (probably *P. parasitica*) non-pathogenic.

P. heveae proved unable to infect seedlings, according to Thompson (219).

P. tabaci infected seedlings, according to Sawada (189).

Lodewijks (122) reported successful leaf inoculations of tobacco with a Phytophthora occurring on *Leucas linifolia*, but Jensen (103) was unable to confirm Lodewijks' results.

Breda de Haan (24) reported *P. nicotianae* on a plant (*androng*) in Java and reported successful inoculations of tobacco leaves placed in contact with those of *androng* under wet conditions.

Of special interest are the results of inoculations by Nolla (144) with Nos. 216 and 247 sent by the writer. He found both capable of causing black shank, but No. 247 proved much slower in causing disease. The writer's results confirm this observation, and indicate that the pathogenicity of the isolations is probably a rather fixed character, and does not fluctuate when the inoculations are made under similar environmental conditions.

The seed bed disease, damping off, caused by *P. nicotianae*, was stated by Jensen (103) to be very similar to infection caused by *Pythium de baryanum*. Nolla sent the writer a culture from damping off plants in Porto Rico which proved to be a Pythium, probably *P. de baryanum*. More than one species of Phytophthora and at least one of Pythium may be responsible for damping off, but the evidence is strong that only *P. nicotianae* can cause typical black shank.

Pepper seedlings.—Young plants of *Capsicum annuum* 4 to 12 inches tall were wounded and inoculated near the base of the stem; the inoculations were made at Mayaguez, P. R. in June, July and Aug., 1928 and July, 1929. All isolations were used except those which failed to grow in culture at room temperature. Five plants were inoculated with each.

Fig. 24.—Pepper plants inoculated near the tip with *P. capsici* (No. 147). Photographed 4 days after inoculation.

Nos. 147 and 253 (*P. capsici*) and No. 241 (*P. hydrophila*), all isolated from Capsicum, caused stem rot and the death of all plants after average periods of 6.6, 3 and 4 days, respectively. No other isolation caused infection.

The experiment was repeated, the inoculations being made in wounds in the tender stem tissues just below the terminal bud, instead of in the hardened tissues at the base. Nos. 147, 241 and 253 again proved the only pathogenic isolations, killing the tips after average periods of 2.8, 2 and 2 days, respectively (Fig. 24). Invasion and killing

was more rapid on the younger tissue and Nos. 241 and 253 again showed slightly more virulence than No. 147. Two isolations of *P. parasitica* from pepper (Nos. 183 and 209) failed to infect in both series. Both were isolated from fruit infections. The three pathogenic isolations were obtained from diseased plants on which stem infections were common.

It will be shown that *P. capsici* and *P. hydrophila* are the same species, separable from *P. parasitica* not only by its pathogenicity to pepper stems, but also by its failure to produce chlamydospores, even in old cultures.

Inoculations of tomato, eggplant, Citrus and other stems with various species often caused small invaded areas around the wounds, evidence of weak pathogenicity. However, most isolations failed to cause lesions or other evidence of infection in pepper stems. A few did produce slight lesions on tender stems at the wound within 21 days; such lesions were caused on 2 or more plants by Nos. 36, 44 and 130 (*P. palmivora*), 247 (*P. nicotianae*) and 263 (*P. parasitica*). None caused death.

Sundararaman and Ramakrishnan (209) failed to infect stems with *P. cactorum* (*P. pini var. antirrhini*); Nolla (144) produced a damping off of young seedlings by inoculation with *P. nicotianae*.

Detached leaves of Bryophyllum pinnatum.—Young leaves of *B. pinnatum* were placed in petri plates containing a few cubic centimeters of water. Small wounds were made and the inoculum inserted under the epidermis of the upper surface. The wounds were kept moist during the following 2 days. Leaves of Bryophyllum, because of their fleshy, succulent character, are more suitable for inoculations in the detached condition than are the leaves of most plants. During the 7 days they were kept under observation the check leaves remained green and turgid, with no symptoms of invasion by saprophytes.

Two or 4 leaves were inoculated with each isolation. The plates were kept in diffused light under laboratory conditions at Mayaguez, P. R., July, 1928 and July, 1929. Infections appeared as dark green watersoaked areas which later became soft and black. After 7 days the extent of the invaded areas varied from 1 cm. in diameter to destruction of the entire leaf.

The following isolations caused infections in at least one leaf: *P. arecae*, *P. cactorum* (7 isolations), *P. cinnamomi* (1 isolation), *P. citrophthora*, *P. cryptogea*, *P. hydrophila*, *P. meadii*, *P. mexicana*, *P. nicotianae*, *P. palmivora* (29 isolations), *P. parasitica* (39 isolations) and *P. drechsleri*. The following did not cause infection: *P. bockmeriae*, *P. cactorum* (8 isolations), *P. colocasiae*, *P. erythroseptica*, *P. palmivora* (13 isolations), *P. parasitica* (19 isolations), and *P. richardiae*.

About two-thirds of the isolations of *P. palmivora* and *P. parasitica* and one-half of those of *P. cactorum* proved able to grow in wounded leaves.

The experiment was repeated with unwounded leaves. The inoculum was placed in a drop of water on the upper leaf surface. After 7 days Nos. 228 and 268 (*P. parasitica* from Bryophyllum) had invaded and caused a black rot of the entire leaf in every case. Moderately severe infections were caused by Nos. 241 (*P. hydrophila*), 238 and 257 (*P. meadii*) in 3 of 6, 2 of 4, and 1 of 2 inoculated leaves, respectively. Slight infections were caused by No. 222 (*P. citrophthora*) in 1 of 4 leaves, by No. 232 (*P. nicotianae*) in 1 of 6 leaves, and by Nos. 22, 123 and 236 (*P. palmivora*) in 1 of 4, 1 of 4, and 2 of 4 leaves, respectively. All other isolations failed to cause infection.

While numerous isolations were able to cause infection and more or less severe rotting of wounded leaves, very few were capable of penetrating and rotting unwounded ones. Nos. 228 and 268 (from Bryophyllum) proved much more virulent than any others. Nos. 241, 238 and 257 probably possess some real power to penetrate intact leaves, but the isolations which caused only small invaded areas infected so few leaves that entrance may have been effected through minute wounds which escaped observation. Their ability to cause infection under natural conditions must be considered very doubtful.

Citrus seedlings.—Seedlings of grapefruit (*Citrus paradisi*) 2 to 8 in. tall were wounded and inoculated near the base, but above the soil level. Five seedlings were inoculated in August 1926, with each of Nos. 1 to 153. After 21 days none showed evidence of infection.

Seedlings of sweet orange (*Citrus sinensis*) 9 to 15 in. tall were wounded and inoculated below the soil level. A piece of wet absorbent cotton was wrapped around the stem at the wound before the earth was replaced. The plants were in boxes about 9 in. in depth which were placed in a tank of water approximately 4 in. deep, and remained in the water 60 days. During this period in an environment supposedly favorable to foot-rot none of the seedlings died. When they were removed and examined no evidence of pathogenicity of any of the isolations was observed.

The results were rather surprising, since the sweet orange is susceptible to foot-rot caused by *P. parasitica* and *P. citrophthora*. Fawcett (72) reported that young lemon trees showed more resistance than older ones. Klotz (112) reported that the trunk bark of the sour orange contains substances possessing an inhibitory or paralyzing influence on the hydrolytic action of diastase and invertase in dried mycelial powder of *P. citrophthora*. The inhibitory agent was much more in evidence in sour orange bark than in lemon bark and he considered it possibly the factor

causing the resistance of the sour orange to *P. citrophthora*. The results of the writer's inoculations indicate that young seedlings of sweet orange are very resistant. A comparison of the actions of the inhibitory substances in the bark and wood of trees of various ages would be of interest.

Breadfruit seedlings.—Seedlings of breadfruit (*Artocarpus incisa*) about 12 in. tall were wound-inoculated near the base at Mayaguez, P. R. in July, 1926. Inoculations were made with Nos. 1 to 146 with negative results.

Erythrina seedlings.—Seedlings of *Erythrina poeppigiana* 3 to 7 in. tall were wound-inoculated just below the first pair of leaves in July, 1926, with Nos. 1 to 153. All remained healthy.

Roselle seedlings.—Seedlings of roselle (*Hibiscus sabdariffa*) 6 to 10 in. tall were wound-inoculated near the base in June, 1926, with Nos. 1 to 153. One isolation (No. 11) infected and killed 3 of 5 inoculated plants after 3, 9 and 14 days. All others failed to infect.

Rubber trees.—Young rubber (*Hevea brasiliensis*) trees 4 to 6 ft. in height were inoculated by wounding the bark deeply enough to cause a flow of latex. The inoculum was placed in the latex and held in place by a piece of absorbent cotton which was kept wet during the following week. Only a limited number of trees were available and inoculations were made in June, 1929, with the following isolations: Nos. 14, 102, 116, 140, 223, and 238 (from Hevea), No. 9 (from cotton), Nos. 22 and 44 (from cacao) and No. 97 (from Erythrina sp.) Five inoculations were made with each isolation, 3 on older stems with brown bark and 2 on young green stems.

Nos. 102, 223, 238, and 22 proved about equally virulent. After 2 weeks the inoculations of green stems had caused blackened areas nearly girdling the stems and extending vertically as far as 2½ inches. The wood under the blackened bark was deeply invaded and browned. Inoculations of more mature stems caused slightly sunken and inconspicuously darkened areas. Scraping away the outer bark revealed oblong cankers, brownish-gray in the centers and bounded by a reddish brown peripheral line about one-eighth inch wide. The fungus grew into the wood and caused a brown discoloration. The cankers were usually about ½ in. wide and 1½ in. long.

Nos. 14, 4, 9, 44 and 97 caused infections resembling the above in general characters but much less severe, both on green and brown stems. On the latter the infected regions appeared normal externally. Below the outer bark infection was apparent as a brown discoloration, but no definitely outlined cankers developed.

No. 116 proved non-pathogenic.

The few inoculations of Hevea stems suggest that *P. palmivora*, (Nos. 102 and 22) and *P. meadii* (Nos. 223 and 238) are equally virulent,

and that isolations from other hosts may infect Hevea, especially at tapping wounds.

Positive results of inoculations of stems with Phytophthoras from cacao were reported by Hartley (93), Reinking (176), Demandt (60), Rutgers (185), and Stoughton-Harris (207).

Thompson (219) found *P. palmivora* from cotton (probably the same isolation as No. 9) capable of producing infections similar to black stripe and patch canker when inoculated into wounded stems.

Reinking (177) found *P. palmivora* from the coconut pathogenic to seedlings; Rutgers (185) reported positive results with an isolation from nutmeg; and Thompson (219) produced infections with isolations from the coconut in Jamaica and India.

Negative results were obtained by Rands (173) with *P. cinnamomi* and by Rutgers (185) with *P. cactorum*, *P. colocasiae*, *P. parasitica* (*P. jatrophae*) and *P. nicotianae*.

Thompson (219) secured infections with *P. heveae* and isolations from *Hibiscus sabdariffa* (probably *P. parasitica*), *Ricinus communis* (*P. parasitica*), tobacco (probably *P. nicotianae*) and *Piper betle* (possibly the isolation identified by Ashby (9) as *P. colocasiae*).

Mature coconut palms.—In July, 1928, 5 coconut palms 10 to 15 years old were inoculated with each isolation by pouring a suspension of hyphae and reproductive organs among the youngest leaves. The palms were not wounded. The following isolations, all from Porto Rico, were used; Nos. 249, 250, (*P. palmivora*) and Nos. 228, 253, 8, 132, 178, and 252 (*P. parasitica*). The inoculations caused no cases of bud rot, nor were rows of spots across the pinnae produced. In previous experiments (226) (227) the writer reported infections with *P. palmivora* isolated from coconut and Sabal palms.

Reports of inoculations of wounded seedling palms are usually positive, e. g., Ocfemia and Roldan (146) produced bud rot with *P. palmivora* from Citrus; Reinking (176) found *P. palmivora* from cacao pathogenic, and Gadd (83) obtained infection with *P. palmivora* from coconut, Areca, Hevea and cacao.

Thompson (217) inoculated palms above the bud with *P. palmivora* from coconut, cotton, Hevea and cacao. Bud rot occurred in 1 of 10 palms inoculated with the coconut isolation, but all others were negative.

The writer (226) has shown that wounding alone of mature palms in the growing point is frequently sufficient to cause death and a watery rot of the soft primordial tissues.

Seal (193) using young potted palms, found *P. palmivora* from coconut, cacao, and Borassus pathogenic to both wounded and unwounded palms. He also obtained bud rot with *P. parasitica* (*P. terrestris*) from tomato.

The evidence varies as to the occurrence of specialized strains capable of causing coconut bud rot and the non-pathogenicity of isolations from other hosts.

General Discussion of Inoculations

The results of the inoculations have been discussed in connection with the tables of data for individual hosts. It seems worthwhile to point out here only the general characteristics of species and the variations in pathogenicity in different isolations of the same species.

P. arecae. A single isolation proved pathogenic to apple fruits and potato tubers, but was non-pathogenic to the other hosts.

P. boehmeriae. A single isolation rotted apple fruits and was weakly pathogenic to tomato fruits, Ricinus seedlings and tomato seedlings. Other hosts were not infected.

P. cactorum. All isolations were virulently pathogenic to apples and non-pathogenic to Ricinus seedlings, cacao seedlings, citrus shoots, and tobacco. One isolation (No. 196) invaded cotton bolls weakly. All attacked potato tubers except No. 192. The isolations varied in pathogenicity to tomato and eggplant fruits; the majority were weakly or non-pathogenic, but Nos. 179, 168 and 200 were virulent on tomato fruits, and No. 184 attacked eggplant fruits severely. Papaw seedlings were invaded virulently by No. 168, while all other isolations were weakly to non-pathogenic. None proved virulent to tomato seedlings and only Nos. 179, 172, and 200 caused even slight infection. Eggplant seedlings were attacked weakly by No. 160, but all others failed to infect them. None attacked cacao, citrus or tobacco stems.

P. cambivora developed slowly in apple fruits and failed to cause infection in all the other inoculations.

P. capsici was more or less pathogenic to apple fruits, potato tubers, tomato fruits, eggplant fruits, tomato, eggplant, Ricinus, papaw and cacao seedlings, and did not attack cotton bolls, Citrus shoots, or tobacco. It has been mentioned that *P. capsici* attacked pepper stems.

P. cinnamomi. The 5 isolations were virulent to apples, weakly to virulently pathogenic to potato tubers, weakly to non-pathogenic to tomato fruits and non-pathogenic in the other inoculations.

P. citricola. A single isolation attacked apples virulently and tomato fruits weakly. It was non-pathogenic in the other inoculations.

P. citrophthora. Three isolations were virulent pathogens on apples, potatoes, tomato fruits and Citrus shoots, weakly to virulently pathogenic to eggplant fruits and seedlings, and non-pathogenic in other inoculations.

P. colocasiae. Two isolations were non-pathogenic in all inoculations, except slight infection of papaw seedlings by one isolation.

P. cryptogea. A single isolation attacked potato tubers, tomato and eggplant fruits, and tomato seedlings virulently. It was only weakly pathogenic to apples and failed to infect the other plants.

P. erythroseptica. A single isolation attacked potato tubers and tomato fruits virulently, apples weakly, and failed to infect in other inoculations.

P. hibernalis. A single isolation was virulent to apples and non-pathogenic to potato tubers and eggplant fruits. This species failed to grow at summer temperatures and was not used in other series of inoculations.

P. hydrophila. A single isolation attacked virulently all inoculated fruits and stems, except cacao, which was slightly infected, and citrus shoots and tobacco, to which it was non-pathogenic. This species was also a virulent parasite in pepper stems.

P. infestans. Of 2 isolations one attacked potato tubers and eggplant fruits while the other was nonpathogenic to both. Both failed to rot apples. No other hosts were inoculated.

P. meadii. Three isolations attacked apples and potatoes vigorously, Ricinus seedlings and citrus shoots weakly, cotton bolls and tomato fruits virulently to weakly, and were weakly to non-pathogenic to eggplant and cacao seedlings. Two attacked eggplant fruits, and all failed to infect papaw, tomato and tobacco plants.

P. mexicana. A single isolation proved virulent to apples, potatoes, tomato and eggplant fruits and tomato and eggplant seedlings. It was weakly pathogenic to papaw seedlings and failed to infect in other inoculations.

P. nicotianae. Three isolations caused severe infections of apples, potatoes, eggplant fruits and seedlings and tobacco. They attacked tomato fruits slightly to severely, and varied from virulently to non-pathogenic to cotton bolls, Ricinus seedlings and papaw seedlings. They were weakly to non-pathogenic to tomato and cacao seedlings and citrus shoots.

P. palmivora. (Typical isolations). All of the 22 isolations attacked apples, No. 272 (a weakly growing one) somewhat more slowly than the others. Certain isolations exhibited marked variations in their general pathogenicity, e. g., Nos. 137, 249, 250 and 9 proved pathogenic in 9 or 10 of the 12 series of inoculations. Others showed a generally weak ability to infect. No. 17 attacked apples only and was the only isolation that did not cause rotting of potato tubers. No. 272 was weakly pathogenic to apples and citrus shoots and failed to infect other plants. It was not used in the potato inoculations.

P. palmivora (Atypical isolations). Of these 21 isolations all attacked apples, but Nos. 136, 116 and 26 rotted them more slowly than the

others. No. 116, like No. 272 (a typical isolation) was a slow grower on all media. Nos. 136 and 116 proved non-pathogenic in the other inoculations and No. 6 infected apples and potatoes only. The isolations, both typical and atypical, which grew rather weakly on culture media proved generally low in infecting power. However, some isolations that were generally non-pathogenic were strong growers on media, e. g., Nos. 17, 136 and 6. No. 136 was stated by Hartley to be the same isolation as No. 126; the former failed to cause infection of 4 hosts which No. 126 was able to invade weakly, and attacked apples weakly while No. 126 grew vigorously in them. These results resemble those obtained by Leonian (117) with cultures derived from a dissociating culture of *P. parasitica* from rhubarb.

The most generally pathogenic atypical isolations were Nos. 22, 36 and 130, all isolated from cacao in Java, each of which proved pathogenic in 9 series of inoculations. There are no significant differences in the pathogenicity of typical and atypical isolations.

P. parasitica. All the 57 isolations attacked apples virulently. Only one (No. 185) failed to rot potato tubers. The species proved more generally pathogenic to various plants than *P. palmivora*. However, similar variations in the infecting ability of the various isolations were observed. Twenty-nine isolations were pathogenic in 9 or more series of inoculations, while 2 (Nos. 185 and 142) infected only 2 hosts and No. 144 was pathogenic to 3. Isolations from pepper (Capsicum), cotton, *Hibiscus spp.*, *Lilium spp.*, tomato, and eggplant were rather uniformly and virulently pathogenic to most inoculated plants.

P. phaseoli. A single isolation failed to rot apples and potatoes. No other inoculations were made.

P. richardiae. A single isolation failed to infect in all inoculations.

P. syringae. Two isolations attacked apples but did not infect potato tubers or eggplant fruits.

P. drechsleri proved unusual in invading apples weakly, while proving virulently pathogenic to potato tubers, eggplant fruits and tomato seedlings. Papaw and eggplant seedlings were slightly infected. Other hosts were not attacked. In general pathogenicity *P. drechsleri* has some characters in common with *P. erythroseptica* and *P. cryptogea.*

These results supply evidence that most of the species cannot be distinguished by their pathogenicity to the plants used. *P. arecae* behaved very similarly to some isolations of *P. cactorum*, *P. cinnamomi*, *P. palmivora*, and *P. parasitica*. *P. boehmeriae* resembled *P. citricola* and certain isolations of *P. palmivora* and *P. parasitica*. *P. cactorum* did not behave very differently from *P. citricola*, *P. palmivora*, *P. parasitica* and other species. In general it attacked fewer plants than *P. palmivora* and *P. parasitica* but certain isolations of the 2 latter species were as

generally non-pathogenic as those of *P. cactorum*. *P. capsici*, *P. citrophthora*, *P. hydrophila*, *P. meadii*, *P. mexicana*, *P. nicotianae*, and some isolations of *P. palmivora* and *P. parasitica* showed similar pathogenicity in most of the inoculations. *P. nicotianae*, however, was the only species which attacked tobacco; and *P. capsici* and *P. hydrophila* were the only ones pathogenic to pepper stems.

P. colocasiae and *P. richardiae* were very similar in failing to infect in nearly every case.

P. cryptogea, *P. erythroseptica*, and *P. drechsleri* showed similarities in invading apples weakly, and potatoes virulently.

P. hibernalis and *P. syringae* behaved alike in the few inoculations made with them.

Since both fruits and seedlings of the tomato and eggplant were inoculated a comparison of the ability of the isolations to produce disease symptoms in different organs of the same host is of interest. The fruits or seedlings of the 2 solanaceous hosts were attacked by 123 isolations, of which 98 were pathogenic to both hosts, 16 attacked the tomato only, and 9 attacked the eggplant, but not the tomato. Of the 114 isolations pathogenic to the tomato 61 infected both fruits and stems, 30 infected fruits only, and 23 infected stems only. The stems were succulent at the time of inoculation and proved nearly as susceptible as green fruits. The frequent reports of stem infections indicate that they are quite susceptible to natural infection. The eggplant was attacked by 107 isolations of which 69 attacked both fruits and stems, 34 attacked fruits only and 4 invaded stems only. It is interesting that the 4 isolations which attacked stems but failed to invade fruits of the eggplant also proved more pathogenic to tomato stems than to fruits. These 4 isolations were Nos. 12, 140, 26, and 145. It has been observed that the inoculations furnish evidence of the existence of biological strains which differ in pathogenicity to host species. It appears that the specialization may extend even further with the development of strains exhibiting selectivity of the organs of the hosts. In addition to the isolations which attacked only fruits or stems of the tomato and eggplant it may be recalled that Nos. 183 and 209, from Capsicum fruits, were non-pathogenic to the stems, while Nos. 147, 241 and 253, from stem diseases, killed inoculated stems very quickly. Here, however, a different species is involved. It will be shown that Nos. 183 and 209 are *P. parasitica*, while Nos. 147, 241 and 253 are *P. capsici*.

OVERWINTERING

To determine the relative abilities of the isolations to survive low temperatures and fluctuations in temperature, cultures on oatmeal agar were placed out-of-doors at Columbia, Mo., during the winters of 1926-27, 1927-28 and 1928-29. The cultures were in test tubes and the cotton plugs were sealed with paraffin to prevent drying out. Sealing the tubers causes unnatural respiration conditions and it is possible that these were a contributing factor in the kiling of the fungi. However, similarly sealed tubes of all isolations were kept at room temperature during the periods of exposure without loss of viability.

It should be emphasized that the behavior of the fungi in culture is probably a poor criterion of their actual ability to overwinter in the soil or in organic matter under natural conditions. As has been stated the purpose was to determine the *relative* abilities of the isolations to survive under similar conditions.

The cultures were examined for reproductive bodies at the ends of the periods of exposure. Their viability was tested by pouring into the tubes potato dextrose agar at about 42°C. The new agar was sloped to cover the growth. Living cultures could often be detected after 2 days by the growth of hyphae into the new medium. Those in which no growth started in 20 days were considered dead.

The cultures exposed during Period I were made at Columbia, Mo., and examined and tested immediately after the end of the period. Those of Periods II and III were made at Mayaguez, P. R., and sent to Columbia, where they were exposed and returned to the writer in Porto Rico by W. E. Maneval. A period of 2 to 3 weeks elapsed between the end of the exposure period and examination.

The periods of exposure were: Period I—Dec. 15, 1926 to Apr. 1, 1927; Period II—Nov. 1, 1927 to May 1, 1928; Period III—Dec. 12, 1928 to March 25, 1929. All cultures were in duplicate, and in Table 22 each "L" and "D" represents two cultures except where it is specifically stated that the letter refers to only one.

The following data will give an idea of the temperature conditions prevailing during the 3 periods of exposure:

	Period I	Period II	Period III
No. of days with a minimum temperature between 11° and 30°F.	48	63	51
No. of days with a minimum temperature between 1° and 10°F.	2	10	20
No. of days with a minimum temperature of 0°F. or lower	2	5	4
Minimum temperature for the period	−8°F.	−9°F.	−5°F.

TABLE 22.—SURVIVAL OF CULTURES ON OATMEAL AGAR EXPOSED TO WINTER TEMPERATURES AT COLUMBIA, MO. L—LIVING; D—DEAD. 1—SPORANGIA; 2—CHLAMYDOSPORES; 3—OOSPORES

No.	Species	Period I		Period II		Period III	
		Reproductive bodies present	Condition of cultures	Reproductive bodies present	Condition of cultures	Reproductive bodies present	Condition of cultures
153	P. arecae	none	D	none	D	------	------
192	P. cactorum	2-3	L	1-2-3	L	------	------
194	" "	1-2-3	L	3	D	------	------
179	" "	2-3	L	------	------	2-3	L
184	" "	2-3	L	1-3	L-one D-one	------	------
189	" "	1-2-3	L	------	------	1-2-3	L
193	" "	2-3	L	1-3	D	------	------
168	" "	2-3	L	1-2-3	D	------	------
172	" "	2-3	L	1-2-3	L	------	------
200	" "	2-3	L	2-3	L	------	------
210	" "	2-3	L	------	------	2-3	L-one D-one
190	" "	1-2-3	L	1-3	L	------	------
243	" "	------	------	------	------	2-3	L
149	" "	2-3	L	3	L	------	------
160	" "	2-3	L	------	------	2-3	D
196	" "	1-2-3	L	3	D	------	------
198	P. cambivora	none	L	none	L	------	------
208	" "	none	L	none	L	------	------
147	P. capsici	none	D	------	------	------	------
253	" "	------	------	------	------	none	D
173	P. cinnamomi	2	L	------	------	2	L
174	" "	------	------	2	L	2	L
195	" "	2	L	2	L	------	------
242	" "	------	------	2	D	2	L
244	" "	------	------	------	------	2	L
154	P. citrophthora	2	L	none	L	------	------
221	" "	------	------	------	------	2	L
222	" "	------	------	2	D	2	D
152	P. colocasiae	1-2	D	------	------	1	D
239	" "	------	------	------	------	1-2-3	D
150	P. cryptogea	3	L	3	L	------	------
176	P. erythroseptica	------	------	------	------	3	D
246	P. hibernalis	------	------	------	------	3	L
241	P. hydrophila	------	------	1-3	D	1-3	D
245	P. infestans	------	------	------	------	1	D
248	" "	------	------	------	------	1-3	D
223	P. meadii	------	------	1-2	D	1-2	D
238	" "	------	------	none	D	2	D
257	" "	------	------	------	------	2	D
148	P. mexicana	none	D	------	------	none	D
216	P. nicotianae	2	L	------	------	1-2	L
232	" "	------	------	1-2	D	2	L
247	" "	------	------	------	------	2-3	D
12	P. palmivora (typ.)	2	L	2	D	------	------
123	" "	1-2	L	1-2	D	------	------
236	" "	------	------	------	------	1-2	L
13	" "	2	L	1-2	L	------	------
127	" "	1-2	D	1-2	D	------	------
137	" "	1-2	D	2	D	------	------
249	" "	------	------	------	------	1-2	L
250	" "	------	------	------	------	1-2	L
265	" "	------	------	------	------	1-2	L
1	" "	2	L	2	L	------	------
3	" "	2	D	1-2	L	------	------
17	" "	2	D	2	L-one D-one	------	------
16	" "	1-2	D	1-2	D	------	------
9	" "	1-2	L	1-2	L	------	------
14	" "	1-2	D	1-2	D	------	------
235	" "	------	------	------	------	none	D
146	" "	2	D	1-2	L	------	------
4	" "	1-2	L	1-2	D	------	------
5	" "	1-2	L	1-2	L-one D-one	------	------
7	" "	1-2	L	2	D	------	------
255	P. palmivora (atyp.)	------	------	------	------	2	D
180	" "	2	L	2	L	------	------
126	" "	2	D	2	D	------	------
136	" "	2	D	2	D	------	------
97	" "	none	D	2	D	------	------
102	" "	none	D	none	D	------	------

TABLE 22.—(CONTINUED)

No.	Species	Period I		Period II		Period III	
		Reproductive bodies present	Condition of cultures	Reproductive bodies present	Condition of cultures	Reproductive bodies present	Condition of cultures
116	" "	none	D	2	D	------	------
140	" "	2	D	2	D	------	------
15	" "	2	D	2	D	------	------
138	" "	2	D	2	D	------	------
18	" "	none	D	2	D	------	------
22	" "	none	D	------	------	1-2	D
26	" "	none	D	1-2	D	------	------
36	" "	2	L	none	D	------	------
44	" "	2	L	2	D	------	------
100	" "	none	D	none	D	------	------
121	" "	2	D	------	------	2	D
6	" "	2	D	2	D	------	------
130	" "	1-2	D	none	D	------	------
141	" "	none	L	none	D	------	------
254	" "	------	------	------	------	2	D
185	P. parasitica	2	L	------	------	1-2	L
228	" "	------	------	none	D	1-2	D
183	" "	2	L	1-2	L	------	------
209	" "	none	L	2	D	------	------
260	" "	------	------	------	------	1-2-3	D
144	" "	none	D	2	D	------	------
178	" "	2	L	------	------	2	D
2	" "	none	L	1-2	D	------	------
8	" "	2	L	2	L	------	------
10	" "	1-2-3	L	1-2	D	------	------
11	" "	2	D	2	L	------	------
258	" "	------	------	------	------	1-2	D
142	" "	none	D	2	D	1-2	D
261	" "	------	------	------	------	1-2	L
262	" "	------	------	------	------	2	L
165	" "	2-3	L	1-2	D	------	------
211	" "	------	------	none	D	2	L
212	" "	------	------	2	D	1-2-3	D
132	" "	1-2-3	L	2-3	D	------	------
162	" "	2	L	------	------	1-2	L-one D-one
177	" "	2	L	2	D	------	------
181	" "	2-3	L	1-2	L	------	------
186	" "	2	L	------	------	2	L
187	" "	2	L	2	L	------	------
191	" "	2	L	------	------	2	L
251	" "	------	------	------	------	1-2-3	L
264	" "	------	------	------	------	2	D
143	" "	none	D	2	D	------	------
217	" "	1-2	D	1-2	D	------	------
259	" "	------	------	------	------	1-2	D
159	" "	1-2-3	L	2	D	------	------
169	" "	2	L	1-2	L	------	------
175	" "	2-3	L	1-2-3	L	------	------
204	" "	2	L	1-2	L	------	------
234	" "	------	------	------	------	1-2	L
139	" "	none	L	2	D	------	------
161	" "	2	L	1-2	L	------	------
182	" "	none	D	1-2	L	------	------
201	" "	2	L	1-2-3	L-one D-one	------	------
202	" "	2	L	2	L	------	------
213	" "	2-3	L	------	------	2	L
252	" "	------	------	------	------	2	D
197	" "	2	L	2	L	------	------
203	" "	2	L	2	D	------	------
207	" "	2	L	2	D	------	------
145	" "	none	D	2	D	------	------
263	" "	------	------	------	------	1-2	D
151	" "	1-2	L	1-2	L-Mone D-one	------	------
164	" "	2-3	L	------	------	1-2	L
166	" "	------	------	1-2	D	1-2	L
167	" "	2	L	------	------	1-2	L-one D-one
171	" "	2	L	1-2	L	------	------
199	" "	------	------	2	D	2-3	L-one D-one
205	" "	2	L	------	------	2	L
227	P. richardiae	------	------	3	D	------	------
156	P. syringae	------	------	3	D	3	L
230	" "	3	D	3	D	------	------
206	P. drechsleri	2	L	2-3	L	------	------

During Period I 200 cultures were exposed, of which 132, 66%, survived; after Period II 67 of 188 cultures, 36%, were alive; and after Period III 60 of 122, 49%, survived. These percentages do not offer a reliable basis for correlating the ability of the isolations to survive with the severity of temperature conditions. Periods I and III were of about the same duration, but many of the isolations tested in Period III were not exposed during Period I. Period II was much longer, and a portion of the deaths may have been caused by the combined effects of unnatural respiration conditions and unfavorable temperatures. These cultures were sealed during more than 7 months.

The following species survived in a majority of the cultures exposed: *P. cactorum* (48 of 60), *P. cambivora*, (8 of 8), *P. cinnamomi* (16 of 18), *P. citrophthora* (6 of 10), *P. cryptogea* (4 of 4), *P. hibernalis* (2 of 2), *P. nicotianae* (6 of 10), *P. parasitica* (117 of 194) and *P. drechsleri* (4 of 4).

All isolations of *P. cactorum* survived at least one exposure period, Oospores were present in all cultures.

P. cambivora was uniformly resistant. No reproductive bodies of any type were found in the cultures.

P. cinnamomi behaved quite uniformly, 16 of 18 cultures surviving. Chlamydospore-like vesicles were abundant in all cultures, but no oospores were seen.

P. citrophthora survived in 6 of 10 cultures. Chlamydospores were found in all but 2 cultures, which consisted of mycelium only, but survived as did the chlamydospore-producing cultures of the same isolation exposed during another period.

P. cryptogea survived in all cultures. Oospores were produced.

P. hibernalis also survived in the 2 cultures used. Oospores were abundant.

P. nicotianae remained alive in 6 of 10 cultures. Nos. 216 and 232 produced chlamydospores and both survived Period III. No. 247 produced chlamydospores and oospores but died during Period III.

P. parasitica offers an opportunity to observe the relative cold-resisting abilities of isolations from tropical regions where freezing temperatures are not encountered, and from temperate regions where the fungi must survive winters similar to those in Missouri. Tropical isolations survived in 40 of 94 cultures, while those from the temperate zone survived in 75 of 96 cultures. The fact that nearly twice as many of the latter were capable of survival suggests that resistance is an inherent character. Only one temperate isolation (No. 212) failed to survive during at least one exposure. Of the tropical isolations Nos. 228, 144, 142, 143, 217, and 145 failed to live through either of 2 periods.

Nos. 260, 258, 264, 259, 252, and 263 failed to survive the only period during which they were exposed.

Statements that various species of Phytophthora overwinter in the oospore stage are quite often encountered. It seems to have been taken for granted, sometimes, that oospores are necessary for survival at low temperatures. An examination of the data indicates that this is not true for *P. parasitica* in cultures. This species is usually rather slow in producing oospores, and a comparison of the numbers of living and dead cultures in this experiment, in which oospores are present after exposure is not significant, since the oospores may have been produced in the warmer period near the end of exposure, after the culture had survived the extreme temperatures in another stage. The cultures were not examined prior to exposure. The finding of oospores in these living overwintered cultures is, therefore, of no importance. Their presence in dead cultures is significant, in that they must have been produced before the period of low temperatures, and have failed to function as resistant spores and to prevent the death of the fungus. Oospores were found in dead cultures of Nos. 260, 212, 201 and 199.

Another significant fact is that numerous isolations of *P. parasitica* survived in every exposed culture, yet showed no evidence of development of oogonia or oospores. Examples are Nos. 185, 183, 8, 261, 262, 181, 186, 187, 191, 169, 204, 234, 161, 202, 197, 171, and 205. These data seem to indicate rather strongly that the ability to survive low temperatures is not correlated with the development of oospores. The resistance of different isolations must be considered characteristic for the particular ones.

P. drechsleri survived in oospore-producing and non-oospore-producing cultures.

Another group of species exhibited rather feeble resistance, a majority of the cultures failing to live through a period of exposure.

P. arecae always died. No reproductive organs were found.

P. capsici did not survive in cultures exposed during Periods I and III.

P. colocasiae did not survive. Cultures producing oospores and those producing chlamydospores or sporangia only proved equally susceptible.

P. erythroseptica did not survive. Oospores were found in the dead cultures. It was exposed during Period III only.

Oospore-producing cultures of *P. hydrophila* failed to survive either of two periods of exposure.

P. infestans did not survive exposure during Period III. Both oospore-producing and non-oospore-producing cultures died. The cultures were sent from Missouri to Porto Rico and the lethal factor for this

species may have been the heat encountered during the trip. The writer has frequently found it difficult to secure living cultures of *P. infestans*, *P. hibernalis*, and *P. syringae* in Porto Rico and to transmit them. However, cultures placed in a refrigerator on the steamer were received in good condition.

P. meadii did not survive in any trial. Chlamydospores were usually present.

P. mexicana, exposed during 2 periods, failed to produce reproductive organs. All cultures were killed.

The isolations of *P. palmivora*, all from tropical regions, are separated into typical and atypical groups, based, it may be recalled, on differences in the profuseness of mycelial development and the abundance of reproductive organs on steamed corn meal. The atypical isolations in general produce a more profuse aerial mycelium and fewer reproductive organs than the typical ones. No oospores were found in any culture.

The two groups show a rather surprising difference in ability to survive low temperatures. Of the cultures of typical isolations 36 of 70 survived. Those that failed to live through even one exposure period are Nos. 127 and 137 (perhaps the same isolation), 16, 14, and 235, the last exposed during only one winter. The atypical isolations, however, survived in the cases of only 10 of 78 cultures. No isolation survived during 2 winters. Nos. 36, 44 and 141 survived Period I but succumbed during Period II. The low resistance of the isolations cannot be attributed to failure to sporulate, since 44 of the 68 dead cultures contained chlamydospores. Age in culture is frequently stated to cause a weakened condition which might become evident as decreased resistance. Most of the atypical cultures are long isolated, but Nos. 254 and 255, more recently isolated, show a similar susceptibility. Furthermore, a number of the atypical isolations which survived have been in culture for about the same length of time as the atypical isolations which perished.

No. 116 of the atypical group shows definite evidence of weakness in culture by its slow and rather meager growth. Whether this weak growth is a character of the isolation or the result of age in culture is unknown. No. 272, a more recently isolated typical isolation, also grew weakly in the writer's experiments. Ashby (9) examined No. 272 when it was younger in culture and found it weak in growth. Most of the atypical isolations equal or exceed the typical isolations in vigor of mycelial development at favorable temperatures. The non-resistance of the atypical isolations is not correlated with a debilitation resulting in weakly growth.

There remain for consideration the factors which Ashby (9) regarded as possible causes of the development of atypical characters in isolations

which appeared to be typical when freshly isolated. These are the maintenance of the fungi on unfavorable substrata or at low temperatures, and, possibly, bacterial contamination. Ashby's (9) division of the isolations was made on the basis of their behavior on agar media, while the writer has classified them by their characters on steamed corn meal; in general our results with the same isolations agree, but the writer found Nos. 1 and 146 typical while Ashby (9) included them in his atypical group. Whether the environment in which the isolations are cultivated is capable of causing profound and permanent changes in the protoplasm, resulting in a loss of power to resist low temperatures, cannot be determined from the data at hand. Tests of the overwintering ability of isolations of which atypical and typical cultures are available would be of interest.

P. richardiae failed to survive during one period. Oospores were produced.

P. syringae is a heat-susceptible species and the killing of cultures may have been caused by high rather than low temperatures. All cultures produced numerous oospores.

The resistance of the isolations, in culture, to low temperatures seems to be determined by the character of the protoplasm of the particular isolation, and not by the development of certain types of reproductive organs. *P. cambivora*, producing mycelium only, proved highly resistant; *P. cinnamomi*, *P. citrophthora*, and certain isolations of *P. nicotianae*, *P. palmivora* and *P. parasitica* which produced asexual reproductive bodies only, were also resistant. Some isolations with oospores in the exposed cultures failed to survive, e. g., *P. colocasiae*, certain isolations of *P. nicotianae* and *P. parasitica*, *P. erythroseptica*, *P. richardiae*, and *P. hydrophila*.

The ability to survive varies in individual isolations of *P. palmivora*, *P. parasitica*, and *P. nicotianae*. In *P. cactorum* resistance is fairly uniform among the 15 isolations studied, and confirms the less variable nature of this species as observed in connection with growth and reproductive characters.

P. infestans, which is not included in the discussion of results, may be an exception in requiring the development of resistant spores to survive exposure to low temperatures. Cultures with and without oospores did not survive, but, as has been noted, the critical factor may have been high rather than low temperatures.

References to the ability of various species to survive low temperatures may be summarized as follows:

P. arecae. Church and Scandiffio (39) reported dying of cultures on potato agar at 0°C. and 7°C. for 2½ months.

P. cactorum. Bartram (13) reported that *P. omnivora* survived a winter of exposure on lima bean agar in Vermont; Rosenbaum (182) found that cultures buried in the earth nearly 2½ winter months in New York survived; Church and Scandiffio (39) found that 3 isolations survived 2½ months on potato agar at 0°C., while an isolation from *Pinus sp.* (*P. pini*) survived at 7°C., but not at 0°C.

P. cambivora. Petri (165) reported that the fungus was not killed by exposure to —16°C. for 10 hours.

P. capsici. Church and Scandiffio (39) reported the survival of cultures on potato agar at 7°C., but death after exposure to 0°C. for 2½ months.

P. citrophthora. Church and Scandiffio (39) reported survival in culture on potato agar after 2½ months at 0°C.

P. colocasiae. Church and Scandiffio (39) reported the death of cultures on potato agar kept 2½ months at 0°C. and 7°C.

P. erythroseptica. Bruyn (27) found that cultures in sterilized soil survived exposure to winter temperatures in Holland; four gelatine cultures with no oospores died, but a large majority of the oospore-producing cultures survived. Church and Scandiffio (39) reported the survival of potato agar cultures kept 2½ months at 0°C.

P. infestans. Jensen (104) reported that the fungus survived in potato tubers buried in the earth during a winter with minimum temperatures near 0°C.; Boehm (21) reported that mycelium in tubers was killed at 0°C.; Angell (4) placed oatmeal agar cultures containing oospore-like bodies, usually without antheridia, out-of doors during January in Canada, but they did not survive; Bruyn (29) found that cultures with oospores and "resting spores" survived exposure for 5 days to temperatures of —20° to —26°C; the cultures proved more resistant when dry than when moist; cultures with only mycelium and sporangia were not resistant. Church and Scandiffio (39) reported *P. infestans* unable to survive 2½ months on potato agar at 0°C., 7°C. or 26-32°C.

Miss Bruyn (27) stated that, "The ability of the mycelium to resist cold is a specific character." The writer's results indicate that in some species it is not a specific character but a character of individual strains.

LONGEVITY IN CULTURE

Cultures of most of the isolations on potato dextrose agar in unsealed tubes were kept in the laboratory at Mayaguez, P. R. one year. They were tested for survival by pouring into the culture tubes sufficient melted potato dextrose agar at about 42°C. to cover the dry agar. In Porto Rico the relative humidity is usually high and cultures do not dry out as quickly as in the drier atmosphere at Columbia, Mo. A test of the ability of the isolations to survive in Porto Rico is, therefore, a less severe one than a similar test in a drier region.

Table 23 shows the species, the number of isolations of each used and the numbers of cultures which survived or died.

TABLE 23.—THE SURVIVAL OF ONE YEAR OLD CULTURES ON POTATO DEXTROSE AGAR

Species	No. of isolations used	No. of cultures living	No. of cultures dead
P. arecae	1	1	1
P. cactorum	14	40	9
P. cambivora	2	4	3
P. cinnamomi	5	6	9
P. citrophthora	3	1	7
P. colocasiae	2	2	5
P. cryptogea	1	1	2
P. hydrophila	1	2	1
P. meadii	2	4	1
P. mexicana	1	3	2
P. nicotianae	3	3	4
P. palmivora (typ.)	17	28	9
P. palmivora (atyp.)	18	35	10
P. parasitica	52	107	30
P. richardiae	1	2	1
*P. syringae	2	8	0
P. drechsleri	1	3	0

*Cultures kept one year at about 10°C.

All species survived in at least one instance. *P. cactorum*, bearing oospores, survived in a large percentage of cases, but *P. palmivora* was nearly equal in resistance, although none of the isolations produced oospores. *P. parasitica*, in cultures with or without oospores showed similar resistance. An examination of Table 23 fails to show any correlation between the ability of species to survive long periods in culture and the development of oospores. *P. cambivora*, with mycelium only, equalled or exceeded in resistance *P. arecae*, *P. cinnamomi*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. mexicana*, and *P. nicotianae*, all of which produced reproductive bodies of one type or another. Typical and atypical cultures of *P. palmivora* were about equal in resistance. Isolations of the same species showed no very marked differ-

ences in resistance and at least one culture of almost every isolation survived.

Additional trials with a smaller number of isolations on oatmeal agar and corn meal agar, which are generally more favorable to growth and development of reproductive organs, gave very similar results, approximately the same percentages of the cultures surviving on these and potato dextrose agar.

Although the conditions in culture are very different from those in the soil in nature, the results of the tests suggest that the Phytophthoras may resist long periods of drought in the soil or in plant tissues, and that their survival is not contingent on the development of oospores.

THE RELATIONS BETWEEN TEMPERATURE AND GROWTH

During Sept., Oct., and Nov., 1929, the isolations were incubated at various temperatures at the Boyce Thompson Institute at Yonkers, N. Y. They were grown in petri plates on corn meal agar prepared from a dehydrated product obtained from the Digestive Ferments Co., of Detroit, Mich. To avoid possible variations in different lots of the medium an amount sufficient for the entire experiment was secured, and the contents of the several containers were thoroughly mixed. The medium was prepared freshly on alternate days and care was used in maintaining uniformity in its preparation and sterilization. The pH of the sterilized agar was 6.2.

Approximately 12 c. c. of the agar were used in each plate. Inoculations of the plates were made from cultures 10 to 16 days old on string bean agar. All inoculations were in triplicate except those incubated at 37.5°C., which were in duplicate. A single bit of inoculum was placed near the center of each plate. The plates were incubated in electric, thermostat-equipped incubators in which the variations in temperature did not exceed about 1.5°C. Variations were usually above rather than below the stated temperatures. The plates were incubated at 5, 10, 15, 20, 25, 27.5, 30, 32.5, 35 and 37.5°C. The mycelial growth in each plate was measured by averaging the greatest and least diameters of the more or less circular growth. The figures in Table 24 are the average diameters of the growths in the plates incubated at each temperature. Growth was measured after 72 and 96 hours, but figures for the latter only are included in the table.

The behavior of conspecific isolations at different temperatures does not vary widely and presents a rather sharp contrast to the marked variability within the species in morphology, growth characters and pathogenicity. This similarity of behavior is especially marked at the upper limits of temperature at which growth occurred, and the species

may be divided into very definite groups on the basis of the highest temperatures permitting their development on this culture medium.

Growth occurred at 35°C. in all isolations of *P. hydrophila*, *P. nicotianae*, *P. parasitica*, *P. drechsleri* and one of *P. capsici*. *P. parasitica*, represented by a large number of isolations, exhibited great diversity in morphology and pathogenicity, yet all isolations proved capable of growth at 35°C., and many at 37.5°C., the highest temperature used in the investigation. The morphological similarity between *P. nicotianae* and *P. parasitica* has been mentioned. *P. hydrophila* and *P. capsici* are also identical in other characters. *P. drechsleri* is distinguishable by morphologic characters.

A large group of isolations grew rather profusely at 30° or 32.5°C., but failed to develop at 35°C. This includes *P. arecae*, *P. bochmeriae*, *P. cactorum*, *P. cambivora*, *P. cinnamomi*, *P. citricola*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. meadii*, *P. mexicana*, *P. palmivora* and one isolation of *P. capsici*. *P. cactorum* has consistently shown less variability between the individual isolations than the other species of which several isolations were used. Their uniformity in temperature response was notable, some growth occurring at 30°C. and little or none at higher temperatures. The same reactions occurred in single isolations of *P. arecae*, *P. citricola* and *P. cryptogea*, and in 3 of *P. citrophthora*. Single isolations of *P. bochmeriae*, *P. cambivora*, *P. capsici*, and *P. mexicana* grew at 32.5°C. In some species the maximum temperature for growth apparently was very near 32.5°, since some isolations grew at this temperature and others did not, e. g., among 5 isolations of *P. cinnamomi* 3 failed to develop above 30°C. while 2 grew at 32.5°C; of 2 of *P. colocasiae* one failed to grow and the other grew at 32.5°C.; of 42 of *P. palmivora* 4 made no growth at 32.5°C.; while 38 grew at this temperature, many of them profusely. However, none proved capable of appreciable growth at 35°C. Typical and atypical isolations behaved very similarly.

The species for which 30° and 32.5°C. were the limiting temperatures may be grouped roughly on the basis of morphologic characters, as follows: 1. *P. arecae*, *P. bochmeriae*, *P. citrophthora*, *P. colocasiae*, *P. meadii*, *P. mexicana* and *P. palmivora* (sporangia papillate; oogonia, if developed, with amphigynous antheridia); 2. *P. cactorum* and *P. citricola* (oogonia with paragynous antheridia); 3. *P. cambivora*, *P. cinnamomi*, and *P. cryptogea* (sporangia non-papillate, rare on solid media; oogonia, if present, with amphigynous antheridia).

P. erythroseptica and *P. richardiae* grew at 27.5°C. but did not grow at 30°C. These species have much in common, morphologically, with those in group 3 above.

P. infestans was represented by 2 isolations, Nos. 245 and 248. No. 245 grew much more vigorously on corn meal agar and developed

TABLE 24.—AVERAGE DIAMETERS OF MYCELIAL GROWTH IN PLATE CULTURES ON CORN MEAL AGAR (pH 6.2) INCUBATED 96 HOURS AT VARIOUS TEMPERATURES. YONKERS, N. Y., SEPT.-NOV., 1929. SLIGHT GROWTH IS INDICATED BY THE LETTER s

No.	Species	5°C. mm.	10°C. mm.	15°C. mm.	20°C. mm.	25°C. mm.	27.5°C. mm.	30°C. mm.	32.5°C. mm.	35°C. mm.	37.5°C. mm.
153	P. arecae	0	0	7	37	51	67	30	0	0	0
266	P. boehmeriae	0	5	14	41	59	37	42	s	0	0
192	P. cactorum	11	17	24	30	40	38	31	0	0	0
194	" "	6	11	21	29	39	40	38	0	0	0
179	" "	s	8	16	25	34	32	28	0	0	0
184	" "	10	14	27	30	32	31	30	0	0	0
189	" "	8	13	20	28	33	33	33	0	0	0
193	" "	10	10	16	27	31	32	7	0	0	0
168	" "	s	14	19	28	29	32	21	0	0	0
172	" "	10	13	15	17	21	28	8	0	0	0
200	" "	s	15	21	32	41	32	s	0	0	0
210	" "	0	9	14	23	32	31	s	0	0	0
190	" "	7	11	15	26	35	27	s	0	0	0
243	" "	s	8	19	26	38	32	30	0	0	0
149	" "	0	14	27	55	57	74	s	0	0	0
160	" "	0	14	34	52	68	68	19	0	0	0
196	" "	6	15	24	34	29	27	28	0	0	0
198	P. cambivora	0	0	6	10	22	25	22	0	0	0
147	P. capsici	0	0	15	26	42	35	28	s	0	0
253	" "	0	s	18	44	57	60	66	65	35	13
173	P. cinnamomi	s	s	23	44	41	34	28	0	0	0
174	" "	0	s	14	33	56	54	45	0	0	0
195	" "	0	12	27	41	40	40	34	0	0	0
242	" "	0	s	15	23	55	71	33	17	0	0
244	" "	0	s	19	38	69	72	59	s	0	0
267	P. citricola	0	10	23	32	42	44	15	0	0	0
154	P. citrophthora	s	7	22	35	51	52	41	0	0	0
221	" "	5	16	26	40	58	51	45	0	0	0
222	" "	5	15	26	38	56	56	35	0	0	0
152	P. colocasiae	0	0	18	28	33	42	43	0	0	0
239	" "	0	0	11	33	57	59	62	17	0	0
150	P. cryptogea	15	17	33	49	59	47	43	0	0	0
176	P. erythroseptica	0	0	s	16	21	54	0	0	0	0
*246	P. hibernalis	8	19	25	26	0	0	0	0	0	0
241	P. hydrophila	0	s	31	54	74	83	85	82	15	0
*245	P. infestans	s	6	7	8	10	0	0	0	0	0
*248	" "	0	0	s	s	0	0	0	0	0	0
223	P. meadii	0	10	24	43	69	66	63	49	0	0
238	" "	0	0	10	34	52	61	50	27	0	0
257	" "	0	7	17	37	48	46	48	s	0	0
148	P. mexicana	0	0	10	34	56	58	49	27	0	0
216	P. nicotianae	0	s	12	22	31	34	30	20	11	0
232	" "	s	7	18	29	57	58	57	69	47	10
247	" "	0	7	21	31	34	44	46	57	19	12
271	P. palmivora (typ.)	0	s	9	31	64	72	62	58	0	0
12	" "	0	0	9	35	54	65	56	36	0	0
123	" "	0	s	13	41	73	77	73	70	0	0
236	" "	0	s	14	37	63	72	74	74	0	0
13	" "	0	0	16	46	65	66	66	40	0	0
127	" "	0	0	15	38	69	78	73	70	0	0
137	" "	0	0	19	31	71	81	75	72	0	0
249	" "	0	s	15	31	69	69	71	79	0	0
250	" "	0	s	15	41	68	77	74	75	0	0
265	" "	0	s	10	23	44	46	44	11	0	0
1	" "	0	s	12	37	69	68	66	60	0	0
3	" "	0	s	19	38	68	68	72	66	0	0
17	" "	0	s	16	42	88	90	90	65	0	0
16	" "	0	s	14	28	53	54	54	16	0	0
9	" "	0	0	10	38	54	68	71	71	0	0
14	" "	0	s	6	19	45	47	55	58	0	0
272	" "	0	0	12	25	27	13	s	0	0	0
235	" "	0	0	17	31	56	62	62	33	0	0
146	" "	0	s	18	37	66	73	76	24	0	0
4	" "	0	s	10	27	57	63	67	74	0	0
5	" "	0	s	16	30	57	60	58	30	0	0
7	" "	0	s	14	48	55	63	66	s	0	0
255	P. palmivora (atyp.)	0	0	5	25	58	61	68	41	0	0
180	" "	0	0	10	20	24	30	33	0	0	0
126	" "	0	0	11	32	38	65	67	35	0	0
136	" "	0	0	23	41	65	68	71	62	0	0
97	" "	0	15	27	60	81	88	82	s	0	0
102	" "	0	6	29	50	49	47	43	0	0	0
116	" "	0	0	0	12	18	24	18	0	0	0

TABLE 24.—(CONTINUED)

No.	Species	5°C. mm.	10°C. mm.	15°C. mm.	20°C. mm.	25°C. mm.	27.5°C. mm.	30°C. mm.	32.5°C. mm.	35°C. mm.	37.5°C mm.
140	" "	0	0	0	21	48	59	64	62	0	0
15	" "	0	0	13	32	59	59	62	30	0	0
138	" "	0	0	20	38	64	68	70	57	0	0
18	" "	0	s	30	42	66	69	62	s	0	0
22	" "	0	16	32	48	53	56	63	0	0	0
26	" "	0	11	26	40	55	57	57	s	0	0
36	" "	0	17	31	46	69	74	71	30	0	0
44	" "	s	13	28	48	67	76	76	26	0	0
100	" "	0	10	23	49	61	57	58	10	0	0
121	" "	0	0	18	35	65	68	63	48	0	0
6	" "	0	s	15	38	70	70	69	62	0	0
130	" "	0	6	34	47	68	74	69	29	0	0
141	" "	0	s	23	40	63	64	73	67	0	0
254	" "	0	0	5	36	59	64	68	48	0	0
185	P. parasitica	0	6	9	24	31	38	51	42	9	0
228	" "	0	0	22	27	37	74	68	65	28	s
268	" "	0	0	20	25	32	41	32	54	32	s
183	" "	0	6	26	31	35	37	40	53	13	13
209	" "	0	8	18	25	33	44	48	55	19	0
260	" "	0	0	10	17	26	28	28	43	7	5
269	" "	0	0	13	34	56	57	60	43	7	0
144	" "	0	0	9	18	31	34	32	33	13	0
178	" "	s	s	12	29	36	39	43	42	24	22
2	" "	s	8	14	19	36	44	44	62	50	41
8	" "	s	9	11	15	27	30	34	30	14	0
10	" "	0	s	11	17	26	31	39	38	6	0
11	" "	s	s	18	18	23	30	34	41	13	0
258	" "	s	s	11	19	27	34	35	45	18	18
142	" "	0	s	9	22	39	42	51	48	49	0
261	" "	s	8	17	30	37	36	38	53	10	0
262	" "	s	10	19	23	37	39	40	47	14	0
165	" "	0	s	21	27	23	25	24	43	29	0
211	" "	0	s	16	19	29	35	33	44	22	20
212	" "	0	11	17	25	32	44	46	56	12	s
270	" "	0	8	16	18	19	19	20	26	18	12
132	" "	0	s	10	13	22	24	26	32	10	0
162	" "	0	0	20	30	28	35	37	36	14	0
177	" "	0	7	16	22	23	22	21	22	12	9
181	" "	s	7	19	26	36	36	36	49	9	s
186	" "	0	6	15	25	32	33	48	35	11	0
187	" "	s	10	22	31	30	29	30	31	11	0
191	" "	s	9	24	24	36	37	37	48	14	0
251	" "	0	8	12	20	32	43	46	52	37	s
264	" "	s	10	22	27	36	37	44	52	45	s
143	" "	s	7	12	18	32	42	45	55	52	33
217	" "	0	0	10	20	32	37	45	26	12	0
259	" "	0	0	15	19	30	35	41	42	10	0
159	" "	0	8	12	19	33	33	38	17	6	5
169	" "	0	7	12	21	42	44	49	50	43	0
175	" "	0	s	17	23	30	29	30	40	14	10
204	" "	0	s	15	31	44	52	46	44	12	8
234	" "	0	s	11	20	24	22	24	23	22	18
139	" "	0	6	12	25	31	28	35	38	37	0
161	" "	0	0	13	19	27	28	29	27	17	14
182	" "	s	11	20	28	33	37	40	45	19	s
201	" "	s	7	21	37	43	45	51	47	13	s
202	" "	s	7	16	25	32	33	39	48	33	23
213	" "	s	11	27	41	41	45	48	49	31	12
252	" "	0	12	22	29	40	47	54	67	64	25
197	" "	s	9	21	29	47	47	49	45	42	23
203	" "	0	s	24	33	58	63	65	67	24	s
207	" "	0	6	13	20	29	38	40	51	18	14
145	" "	0	7	15	18	28	37	39	50	18	10
263	" "	s	10	25	40	60	56	61	56	11	9
151	" "	0	7	15	23	27	28	29	28	18	0
164	" "	0	6	15	18	22	25	25	32	14	s
166	" "	0	8	17	24	29	27	28	28	14	0
167	" "	0	11	22	32	39	38	39	47	6	s
171	" "	0	8	16	23	30	31	34	39	13	8
199	" "	0	s	14	33	45	45	48	46	15	0
205	" "	0	8	16	22	30	31	34	37	12	8
227	P. richardiae	0	0	13	26	19	8	0	0	0	0
*156	P. syringae	6	8	30	37	0	0	0	0	0	0
*230	" "	5	13	23	38	0	0	0	0	0	0
206	P. drechsleri	0	6	11	35	49	68	69	71	38	s

*Incubated 120 hours

at 5° to 25°C. No. 248, a very slow grower, developed meagerly at 15° and 20°C. only. It has been noted that No. 245 failed to invade potato tubers and eggplant fruits, both of which were attacked by No. 248. No. 245 failed to develop oospores, while No. 248 produced them quite regularly.

P. hibernalis and *P. syringae* failed to grow at 25°C. These species also appeared very similar in morphologic, pathogenic and growth characters.

A consideration of the optimum temperatures, as indicated by the diameter of the mycelial growth, seems to indicate that the isolations of particular species vary considerably. The variations, on account of the changes in the character of the mycelial growth which occur with changes in temperature, are probably more apparent than real. For example, an isolation incubated at 27.5°C. may develop in an appressed or submerged, radiate, thin, widely-spreading fashion, while at 30°C. the same isolation may produce a thick, tufted growth in the agar with a profuse development of aerial mycelium. The latter type of development tends to spread over the plate slowly and a comparison of the diameters of the differing types of growth does not suffice to determine in which the more profuse development of hyphae has occurred. Some isolations spread almost equally through a temperature range of 10°C. or more, but vary widely in the thickness of the submerged growth and in the profuseness of aerial development. The writer does not consider the diameters of growth at different temperatures a reliable criterion for the determination of exact optima in this genus.

A general idea of the most favorable temperatures for hyphal development may be obtained for each species. *P. hibernalis*, *P. infestans*, *P. richardiae* and *P. syringae* have optima below 25°C. *P. richardiae* was the only species of this group which made any growth above 25°C. and its optimum may be near that temperature. The optima for the others are probably considerably below 25°C. Since no cultures were incubated at temperatures between 20°-and 25°C., and 15° and 20°C., only approximate estimates may be made from the data.

The most favorable temperatures for the growth of a number of species seem to be 25° to 27°C. In this group occur *P. boehmeriae*, *P. cactorum*, *P. cinnamomi*, *P. citricola*, *P. citrophthora*, *P. cryptogea*, *P. erythroseptica*, and *P. mexicana*. *P. erythroseptica* developed most profusedly at 27.5°C., but failure to grow at 30°C. indicates that its optimum is probably between 25° and 27°C.

P. arecae, *P. cambivora*, *P. colocasiae*, *P. meadii* and *P. palmivora* develop most abundantly at 27° to 30°C. The typical and atypical isolations of *P. palmivora* exhibited no important differences.

P. hydrophila, *P. nicotianae*, one isolation of *P. capsici*, *P. parasitica* and *P. drechsleri* grew most luxuriantly at or slightly above 30°C.

The lowest temperatures at which growth was apparent after 4 days varied considerably within the species, and the uniformity of behaviour at the higher limiting temperatures which seems to be a specific character, is lacking at the lower temperatures.

TABLE 25.—NUMBER OF ISOLATIONS OF VARIOUS SPECIES WHICH SHOWED GROWTH AFTER 4 DAYS AT A MINIMUM TEMPERATURE OF:

Species	5°C.	10°C.	15°C.	20°.
P. arecae	0	0	1	0
P. boehmeriae	0	1	0	0
P. cactorum	12	3	0	0
P. cambivora	0	0	1	0
P. capsici	0	1	1	0
P. cinnamomi	1	4	0	0
P. citricola	0	1	0	0
P. citrophthora	3	0	0	0
P. colocasiae	0	0	2	0
P. cryptogea	1	0	0	0
P. erythroseptica	0	0	1	0
*P. hibernalis	1	0	0	0
P. hydrophila	0	1	0	0
*P. infestans	1	0	1	0
P. meadii	0	2	1	0
P. mexicana	0	0	1	0
P. nicotianae	1	2	0	0
P. palmivora	1	25	15	2
P. parasitica	17	31	9	0
*P. syringae	2	0	0	0
P. drechsleri	0	1	0	0

*After 5 days.

Of the species represented by more than one isolation *P. cactorum*, *P. citrophthora*, and *P. syringae* were usually capable of making some growth at 5°C.; isolations of *P. cinnamomi*, *P. meadii*, *P. nicotianae*, *P. palmivora*, and *P. parasitica* most frequently grew at a minimum of 10°C.; and *P. colocasiae* failed to grow below 15°C. One of 43 isolations of *P. palmivora* made some growth at 5°C., while 17 of 57 of *P. parasitica* were capable of development at this temperature.

Further examination of the data for *P. parasitica* shows that 6 of 23 isolations from the temperate zone and 11 of 31 from the tropics grew at 5°C. It is evident that the climatic source of an isolation does not determine its ability to grow at 5°C. A similar examination of the maximum temperatures shows that 16 of 23 isolations from temperate regions and 17 of 31 from the tropics grew at 37.5°C., and indicates that the tropical isolations are not generally more thermophilic than those from the temperate zone. Since the tropical isolations have existed in an environment not subject to great temperature variations it might be expected that they would be less adapted to growth over a wide range of temperatures than those from temperate regions, which, at different

seasons, must endure widely varying conditions. Of 16 isolations of *P. parasitica* which failed to grow at either 5° or 37.5°C., 11 are tropical and 5 temperate, or 33 and 22 per cent, respectively, of the total number of isolations in each group. Of 11 isolations which grew at both 5° and 37.5°C. 7 are of tropical and 4 of temperate zone origins. This evidence does not indicate that the relationships of growth to temperature are altered by the environment in this species, and it is probably safe to assume that the relationships are fairly constant for the species investigated, especially the ability of conspecific isolations to develop at temperatures near the maximum of their range of tolerance.

The plates in which growth did not occur at 35°C. for 96 hours were kept at room temperature one week longer.

TABLE 26.—THE EFFECT OF INCUBATION 96 HOURS AT 35°C. ON SUBSEQUENT GROWTH ON CORN MEAL AGAR IN PETRI PLATES AT ROOM TEMPERATURE

No.	species	No. plates in which growth occurred	No. plates in which no growth occurred
153	P. arecae	0	3
266	P. boehmeriae	2	1
192	P. cactorum	0	3
194	" "	3	0
179	" "	2	1
184	" "	3	0
189	" "	2	1
193	" "	0	3
168	" "	2	1
172	" "	0	3
200	" "	3	0
210	" "	2	0
190	" "	2	1
243	" "	3	0
149	" "	0	3
160	" "	0	3
196	" "	0	3
198	P. cambivora	0	3
173	P. cinnamomi	3	0
174	" "	1	1
195	" "	1	2
242	" "	0	3
244	" "	0	3
267	P. citricola	0	3
154	P. citrophthora	0	3
221	" "	0	2
222	" "	0	3
152	P. colocasiae	0	3
239	" "	1	2
150	P. cryptogea	0	3
176	P. erythroseptica	0	2
223	P. meadii	1	2
238	" "	0	3
257	" "	0	3
148	P. mexicana	0	3
271	P. palmivora (typ.)	3	0
12	" "	3	0
123	" "	3	0

TABLE 26.—(CONTINUED)

No.	species	No. plates in which growth occurred	No. plates in which no growth occurred
236	" "	1	1
13	" "	2	1
127	" "	2	1
137	" "	3	0
249	" "	3	0
250	P. palmivora (typ.)	3	0
265	" "	3	0
1	" "	1	2
3	" "	2	1
17	" "	3	0
16	" "	1	1
9	" "	3	0
14	" "	0	2
272	" "	0	3
235	" "	1	2
146	" "	3	0
4	" "	0	3
5	" "	0	2
7	" "	0	3
255	P. palmivora (atyp.)	3	0
180	" "	0	3
126	" "	3	0
136	" "	1	2
97	" "	0	3
102	" "	0	3
116	" "	0	3
140	" "	1	1
15	" "	3	0
138	" "	1	2
18	" "	1	2
22	" "	0	3
26	" "	0	3
36	" "	2	1
44	" "	0	3
100	" "	0	3
121	" "	0	3
6	" "	2	1
130	" "	0	3
141	" "	3	0
254	" "	2	1
227	P. richardiae	0	3

Plates inoculated with *P. hibernalis* and *P. syringae* were incubated 96 hours at 30°C., removed and incubated at 20°C. for one week. No growth occurred.

P. erythroseptica failed to grow when kept at room temperature after 96 hours incubation at 30°C., but *P. richardiae* survived and grew readily at the lower temperature.

The following species usually failed to survive in small bits of inoculum incubated 96 hours at 35°C.; *P. arecae*, *P. cambivora*, *P. citricola*, *P. citrophthora*, *P. colocasiae*, *P. cryptogea*, *P. erythroseptica*, *P. meadii*, *P. mexicana* and *P. richardiae*. A single isolation of *P. boehmeriae*

survived in 2 of 3 plates and *P. cinnamomi* survived in 5 of 14 plates. *P. cactorum* survived or died in equal numbers; Nos. 194, 184, 200, 210, and 243 lived in all exposed plates, while Nos. 192, 193, 149, 160 and 196 died; the other isolations survived in at least one of 3 plates.

Of the inoculations with typical isolations of *P. palmivora* 40 survived and 22 perished at 35°C., while of the inoculations with atypical isolations 22 lived and 43 died, the proportions of surviving inocula being nearly reversed. That this difference in susceptibility is probably correlated with the host origins of the isolations rather than with their typical or atypical characters is shown by an examination of the behaviors of isolations of both groups from cacao and rubber. Nos. 14, 4, 5 and 7, typical isolations from these 2 hosts, always failed to survive, Nos. 102, 116, 140, 18, 22, 26, 36, 44, 100, 121, 6, 130 and 141, atypical isolations from the same hosts, survived in 9 of 38 plates. *P. palmivora* from cacao and rubber is low in resistance. *P. meadii*, which is frequently isolated from rubber trees, also exhibits weak resistance.

P. palmivora from Citrus (Nos. 180, 249, 250 and 265) survived in 3 of 4 cases, while isolations of a similar species. *P. citrophthora*, from the same host genus, always died.

Plates in which growth did not begin during 96 hours incubation at 5°C. were kept at room temperature for one week. Growth occurred in nearly all, the only exceptions being Nos. 102, 116, and 140 (*P. palmivora* from Hevea in Java) and No. 153 (*P. arecae*), none of which survived.

The data on the influence of temperature on growth were obtained on corn meal agar of pH 6.2. It is very probable that the reactions of the isolations to various temperatures vary with the medium and its hydrogen-ion concentration. Since these data were obtained under very uniform conditions they may be considered reliable criteria for the relative behavior of the various species and isolations. It is apparent that the species vary widely in their temperature requirements and that they may be grouped on the basis of their ability to develop at temperatures near their upper limits. Isolations of the same species exhibit very uniform behavior at the higher temperatures. The ability to survive 4 days of exposure to temperatures too high for growth varies in the individual isolations of most species, while nearly all are capable of surviving at temperatures slightly below the minima at which growth occurs.

The use of the ability to grow at certain temperatures as a criterion for the identification of species seems to be justified, especially in connection with morphologic characters. It is regrettable that a number of species were represented in the investigation by only one isolation, but

the uniformity of behavior of the isolations of *P. cactorum*, *P. cinnamomi* *P. palmivora*, *P. parasitica* and other species represented by several indicate that the ability to develop at the higher temperatures is a specific character. Although slight variations occur within the species the variations are too slight to interfere with the proper grouping of the isolations.

An example of the value of temperature relations as an adjunct to morphologic and growth characters in taxonomy may be cited. The writer received Nos. 2 and 145 labelled *P. faberi* (*P. palmivora*), a species in which oospores were unknown in single strain cultures. The isolations resembled atypical ones which are difficult to distinguish from *P. parasitica*. In 1928 the writer (228 observed oospores in single strain cultures of both isolations. Cultures were sent to Ashby (9) who confirmed the writer's "discovery" of oospores in single strain cultures of *P. palmivora*. When grown at various temperatures both Nos. 2 and 145 grew at 35°C. and even at 37.5°C., but no other isolations of *P. palmivora* grew at 35°C. All isolations of *P. parasitica* grew at 35°C., and since Nos. 2 and 145 showed no differences from the latter in growth characters, type of antheridium, morphology of reproductive organs or pathogenicity it seems clear that they should be classified as *P. parasitica* rather than *P. palmivora*. Further mention of the use of temperature relations as taxonomic criteria will be made in discussing the taxonomy of the species.

Most isolations which grew at the higher temperatures ceased to grow during the fourth day of incubation at temperatures near their maxima. *P. parasitica* which usually grew very well at 35°C. and frequently developed less freely at 37.5° may be used as an example of this early staling and cessation of growth. Twenty isolations that grew at 35°C., but not at 37.5°C. showed an average increment in the diameter of mycelial growth during the fourth day of 8.1 mm. at 32.5°C., and of only 1.8 mm. at 35°C., a difference much more marked than the differences in mycelial growth at the two temperatures for the entire 4-day period. Thirty-seven isolations that made some growth at 37.5°C. made an average increment in diameter during the fourth day of 10.6 mm. at 32.5°C., of 3.2mm at 35°C. and of only .8 mm. at 37.5°C. Fawcett (75) has reported similar observations on *P. parasitica* and *P. citrophthora*. It is probably a common phenomenon among fungi capable of growing at temperatures considerably above the optimum.

P. palmivora failed to grow at 35°C. A similar examination of the increments during the fourth day at the 3 highest temperatures at which growth occurred shows an average increment at 27.5°C. of 17.1 mm., at 30°C. of 17.7 mm., and at 32.5°C. of 12.6 mm. It has been noted that the optimum for this species is between 27.5° and 30°C., and the

increments in growth during the fourth day at these temperatures are about the same. At 32.5°C. there is a diminution of growth but no staling resulting in almost complete cessation. Since no growth occurs at 35°C. it is apparent that the temperature at which early staling occurs lies between 32.5° and 35°C.

The species are often very sensitive to small increases in temperatures above the optima. *P. erythroseptica* grew very profusely at 27.5°C., but at 30°C. growth not only failed to occur but the fungus died. *P. palmivora* usually grew well at 32.5°C. but made no development and

Fig. 25.—*P. colocasiae* (No. 152). Growth on corn meal agar after 96 hrs. at 27.5°C. (x2).

frequently perished at 35°C. *P. parasitica*, however, is more resistant to high temperatures.

The curves in Fig. 30 of the average growth at different temperatures by *P. syringae*, *P. cactorum*, *P. palmivora* and *P. parasitica* illustrate their temperature requirements and demonstrate the sharp decrease in growth as the temperature increases above the optimum. The data on which the curve for *P. syringae* is constructed include the data for *P.*

hibernalis, which, for reasons to be given, is considered synonymous with *P. syringae*.

Observations on the temperature requirements of various species are numerous in the literature, but no one seems to have made a study of any considerable number of species under uniform conditions. The results of the observations recorded for each species will be mentioned.

P. cactorum. Cooper and Porter (48) reported the optimum temperature for *P. paeoniae*, probably the same as No. 243, between 22°

Fig. 26.—*P. cactorum* (No. 184). Growth on corn meal agar after 96 hrs. at 27.5°C. (x2).

and 26°C. Rose (179) reported the optimum between 25° and 36°C., and failed to obtain growth at the latter temperature. Beach (14) reported a maximum of 33°C., an optimum of about 25°C., and a minimum of 7-9°C. for his rhubarb isolation.

P. cambivora. Petri (164) found 20-25°C. the optimum for mycelial growth and the maximum tolerable temperature 45°C. In the writer's work the fungus failed to survive 4 days at 35°C.; Petri's maximum tolerable temperature was probably determined by much shorter ex-

27°Are.

P. citrophthora. Fawcett (73) reported the cardinal temperatures for radial mycelial growth as follows: minimum 10°C., optimum 28°C., maximum 33°C. Later (75) he studied growth increments during the first five 24-hour periods in culture, and reported the maximum temperature for the first period as 36°C., which decreased to 31°C. for the fifth day; the optimum for the first period was 27.5°C. and for the fifth, 24°C. He stated (76) that the fungus does not make much growth

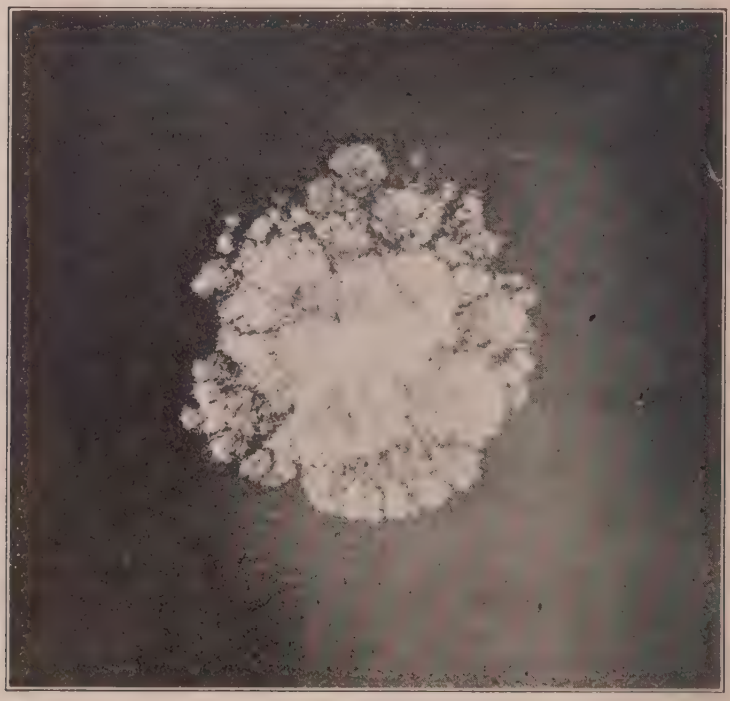

Fig. 27.—*P. parasitica* (No. 234). Growth on corn meal agar after 96 hrs. at 27.5 C. (x2).

in culture above 30°C. G. L. Fawcett (71) reported that a fungus similar to *P. citrophthora* did not survive several days exposure at 36°C.

P. colocasiae. Butler and Kulkarni (36) reported that the sporangia liberated zoospores at 25°C., but not at 32°C.

P. cryptogea. Bewley (19) reported the optimum temperature about 25°C.; below 12°C. growth was very slow. He later (20) reported that sporangia and mycelium in water were killed by one minute at 50°C.

P. hibernalis. Adam (1) found oranges stored at about 3°C. attacked by a fungus which Carne (37) considered *P. hibernalis.* Carne (37) found it very susceptible to heat in culture and considered its optimum temperature probably below 15°C., and the maximum below 25°C. Bensaude (15) obtained most rapid growth at 18° and 20°C.; the fungus died quickly at 25° and 26°C.

P. infestans. Von Holle (230) inoculated detached potato leaves and found the incubation period shorter at 17.5°C. than at 13°C. and 19°C. Jensen (104) obtained most rapid development of infection in inoculated potato tubers at 18-23°C.; at 5°C. development was slow, and at 25°C. infection did not occur. Sporangia died at 25°C. in 84 hours, and much more quickly at higher temperatures. Exposure of infected tubers at 35°C. for 16 hours, or at 25°C. for 90 hours killed the mycelium. Hecke (96) reported temperatures of 18-21.4°C. most favorable to germination and growth in liquid cultures; at 25.6-30° germination was weak and no development of mycelium occurred. Matruchot and Molliard (126) observed active growth in pumpkin infusion at about 15°C.; at 30°C. growth ceased. Jones, Giddings and Lutman (108) reported the best development on agars at 16° and 19°C.; below 5°C. and above 30°C. growth was inhibited. Melhus (135) reported that inoculated plants showed symptoms of infection more quickly at 23-27°C. than at lower temperatures. He found 12-13°C. the optimum and 24-25°C. the maximum temperatures for zoospore formation, but the germination of sporangia by germ tubes was most common at about 24°C. and ceased near 30°C. The development of mycelium in potato tissues was favored by a temperature of about 24°C. Darnell-Smith and MacKinnon (51) reported 15.5-21°C. the optimum temperature; no sporangia developed in cultures above 25°C., and no mycelial growth above 30°C. Clinton (44) obtained no growth on oat agar at 29-30°C. Johnson (105) reported growth on potato agar at 35-36°C.; inoculations of plants at high temperatures gave positive results and he concluded the fungus is "a relatively vigorous parasite at temperatures as high as 32-35°C." His inoculations indicated an optimum of 25-32°C. Nicholls (143) reported that mycelium in tubers was destroyed by 4 hours at 40°C., and Pethybridge (161) found 2 hours at 40°C. sufficient to kill the fungus. Lohnis (124) reported zoospore production most rapid at 8-15°C. Murphy (140) found that sporangia in soil at 30°C. in a saturated atmosphere, survived 26 days. Simonet (199) obtained maximum growth on bean agar at 14-18°C.; little growth occurred below 14°C., and at 30°C. the fungus died in a few days. Vowinckel (231) inoculated detached potato leaves kept at various temperatures and found 19-22°C. the most favorable, but infection also occurred at 29°C.; sporangia developed at 26°C. but not at 27°C. In inoculated tubers some development of mycelium occurred at

all temperatures between 3.2° and 30.3°C., but the optimum was 19-21.5°C.; fairly good penetration occurred at 11.4-27.3°C. McAlpine (130) found that mycelium in tubers survived 4 hours at 43°C., but not at 49°C.

The evidence indicates an optimum temperature below 25°C. and marked susceptibility to much higher temperatures. The results secured by Johnson (105), growth on potato agar at 35-36°C., and infection of plants at 32-35° C., suggest that he was working with another species, possibly *P. parasitica* or one resembling *P. drechsleri*.

P. mexicana. Hotson and Hartge (100) reported that temperatures of 8-10°C. favored oospore formation, which was retarded at 20°C. or above.

P. nicotianae. Tisdale (222) reported little growth in media at 10-14°C. and increasing growth up to 35°C.; sporangia were produced on potato dextrose and oat-meal agars at 20-35°C. Later (223) he reported an optimum temperature of about 30°C. Tisdale and Kelley (225) using potato dextrose agar of various acidities found that growth always occurred at 35°C., but not at 37°C.; growth was usual at 13°C., but not at 8°C.; the optimum was between 25° and 35°C. The writer's results on corn meal agar with No. 216, sent by Tisdale, agree very closely with these observations.

P. palmivora. Reinking (177) studied isolations from coconut and cacao; both failed to grow below 12°C., made their best development at about 27°C., and grew very well at 32°C. Gadd (80) reported temperatures of 20-25°C. favorable to zoospore formation. Seal (193) studied isolations from coconut, cacao and Borassus and observed optima of 28-32°C.; the maximum temperatures at which growth occurred varied with the substratum, and good growth at 38°C. by the writer's No. 1 was reported on certain media. The writer failed to obtain growth at 35°C. on corn meal agar. Ashby (9) reported 27-28°C. the optimum for the species.

P. parasitica. Fawcett (75) reported a maximum temperature of 38°C. for the first 24-hour period in culture and 35°C. for the fifth 24-hour period; the optima were 34°C. and 28°C. for the same periods. Bewley (19) reported about 30°C. the optimum; growth was very slow below 12°C. Rosenbaum (184) reported that immersion of tomato fruits in water at 60°C. for 1½ min. destroyed mycelium near the surface, and Bewley (20) found that hyphae and sporangia in water were killed by one minute at 60°C. Kendrick (109) reported that the species developed best at about 30°C. Williams (235), using an isolation from cucumber, obtained approximate cardinal temperature of 7°C. (minimum), 35°C. (optimum) and 44°C. (maximum). Godfrey (86) grew a rhubarb isolation on corn meal agar and reported cardinal temperatures of 13°C., 30°C.,

FIG. 28.—*P. citrinum* (No. 222). Growth on corn meal agar after 96 hrs. at 27.5°C. (x2).

and 36°C. Beach (14) reported studies on another rhubarb isolation which determined the cardinal temperatures as near 13°C., 30°C., and 36°C.

Fig. 29.—*P. palmivora* (No. 236). Growth on corn meal agar after 96 hrs. at 27.5 C. (x2).

The results obtained by the writer generally agree with the published observations, which increases the evidence that the temperature relations of the species do not undergo marked variations in isolations

kept long in culture, and that different isolations of the same species do not vary widely in their reactions to different temperatures.

The type of growth on corn meal agar varies in different isolations of the same species, and the same isolation produces growth of quite variable appearance at different temperatures. Figs. 25, 26, 27, 28 and 29

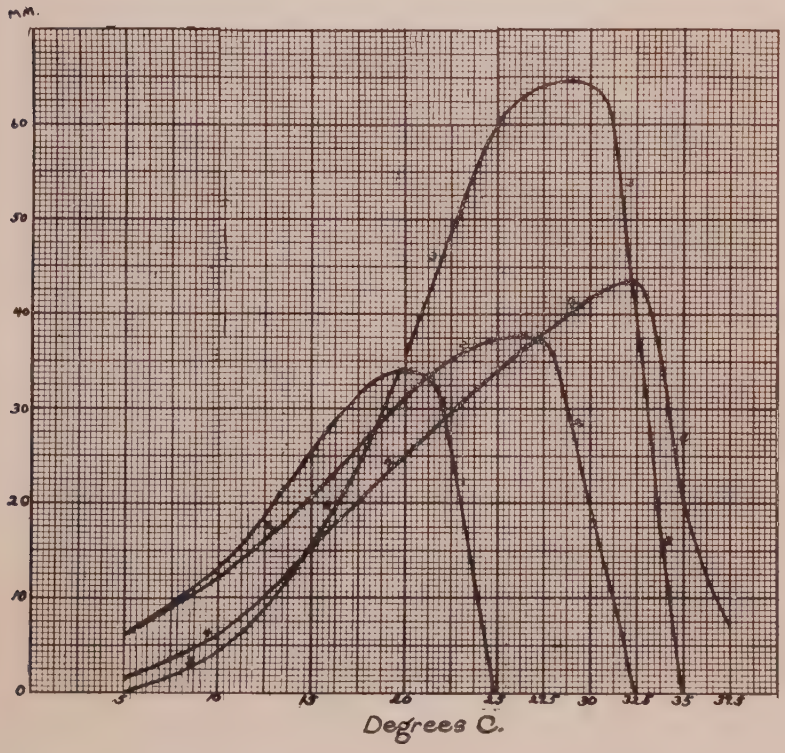

Fig. 30.—Temperature-growth curves for 4 species of Phytophthora. Mycelial growth in millimeters after 96 hours incubation on corn meal agar (pH 6.2), in petri plates at various temperatures. (1) *P. syringae*; (2) *P. cactorum*; (3) *P. palmivora*; (4) *P. parasitica*.

illustrate the types of growth on corn meal agar at 27.5°C. which may be considered fairly typical for *P. colocasiae*, *P. cactorum*, *P. parasitica*, *P. citrophthora* and *P. palmivora*. On account of the wide variations between individual strains, especially in *P. parasitica* and *P. palmivora*, the type of growth is not of much value for distinguishing species.

HETEROTHALLISM AND HYBRIDISM IN PHYTOPHTHORA

Clinton (43) considered that the failure of *P. infestans* to produce oospores in his cultures was possibly due to the existence of heterothallism and the necessity of the presence of both antheridial and oogonial strains. He attempted to demonstrate heterothallism in *P. phaseoli* which produces oospores abundantly, but was unable to obtain single strain cultures in which oospores did not develop. He also failed to obtain oospores of *P. infestans* by growing different isolations together. Later (44) he reported that in mixed cultures of *P. infestans* and *P. phaseoli* mature oospores of the *P. infestans* type occurred more abundantly than in pure cultures of *P. infestans*. He supposed them to be hybrids between the two species, and, observing unfertilized oogonia in cultures of *P. infestans*, believed that it had largely lost the ability to produce antheridia. He assumed that *P. phaseoli* supplied the antheridia which made possible the more abundant production of mature oospores by *P. infestans* in mixed cultures. He also reported a few oospores, which he considered probably hybrids, in mixed cultures of *P. infestans* and *P. cactorum*. His evidence of hybridism is not very convincing.

More recent investigations have resulted in numerous reports of the development of oospores in single strain cultures of *P. infestans*. The writer's No. 248 produced them regularly.

Ashby (7) in 1922 obtained oospores in mixed cultures of *P. palmivora* from cacao, coconut and cotton. None appeared in pure cultures. The cacao strain was considered the *minus* race and the coconut and cotton strains *plus* races. The antheridia were amphigynous and the oospores averaged 23-24μ in diameter. He grew an isolation of *P. parasitica* that produced oospores with an average diameter of 18.6μ in mixed cultures with the cacao strain of *P. palmivora* and obtained oospores in the zone invaded by *P. palmivora* which averaged 23.6μ in diameter. These he considered the oospores of the cacao fungus.

Gadd (79) in 1924 found oospores in mixed cultures of several isolations of *P. palmivora* from various hosts in Ceylon. The oogonia and antheridia resembled those reported by Ashby (7), and the oospores had a mean diameter of 23-24μ. He divided his strains into *plus* and *minus* groups, and considered heterothallism the probable explanation of their behaviour when two strains of different groups were grown together, and later (83) in 1927 he concluded that the evidence definitely established the existence of heterothallic strains in *P. palmivora*.

Lester-Smith (120) in 1927 also obtained sexual spores in mixed cultures of *P. palmivora*. When he grew *P. palmivora* with *P. parasitica* which produced small oospores he obtained oospores larger than those

of *P. parasitica* and considered them produced by *P. palmivora*. The smaller oospores of *P. parasitica* were also present. He construed his results as offering no evidence of either hybridism or heterothallism and suggested that the formation of sexual organs may be related to the rate of metabolism of the thallus which is largely influenced by the environment, and that their formation is favored by a low rate of metabolism produced by a low water content, a different ratio of food materials and, possibly, a low temperature. He stated that the production of oospores in mixed cultures "is due to the influence of the one vegetation on the other, acting through its effect on the medium or on certain constituents of the medium."

Lester-Smith (120) grew an isolation of *P. nicotianae* which did not form oospores in pure culture with *P. palmivora* and obtained oospores. When *P. nicotianae* was grown with a culture of *P. parasitica* which formed small oospores, larger oospores appeared and were attributed to *P. nicotianae*. The fact that *P. nicotianae* is very similar to *P. parasitica* would cause one to expect it to behave very similarly in mixed cultures.

Dade (50) in 1928 obtained oospores in mixed cultures on cacao pods with 2 strains of *P. palmivora* from the Gold Coast.

Ashby (8) in 1928 induced oospore development in some strains of *P. parasitica* which did not produce them in pure culture by growing them with some other isolations of the same species. In an old mixed culture of *P. parasitica* (which produced oospores with a mean diameter of about 19μ) with *P. cinnamomi* he found large oospores, 30μ and above in diameter, which he considered those of *P. cinnamomi*.

In 1929 Ashby (9) reported that oospore development in mixed cultures of *P. palmivora* on corn meal agar at room temperatures was more profuse in England than in the tropics. In England the oospores appeared promptly (4-5 days) or not at all. He agreed with Lester-Smith's (120) view that the formation of oospores in mixed cultures is due to the biochemical stimulation of one mycelium by the other and that the same mycelium produces both antheridia and oogonia. Ashby's (9) observations of oogonia and oospores in both growth zones of mixed cultures and the fact that these sexual bodies, produced in different zones, showed variations in the shape of the oogonia and the size of the oospores, indicated that each strain was producing its own characteristic oogonia and oospores. His observations, he concluded, supported the theory of biochemical stimulation rather than heterothallism. The production of oospores by *P. palmivora* in mixed culture with *P. parasitica* was attributed to the "setting in of conditions under which sexual organs can develop in the other vegetation, possibly by removing inhibiting substances."

Ashby (9) also reported oospores in the growth zone of *P. cryptogea* after 10 days in mixed cultures with *P. cinnamomi*. Their size and appearance corresponded closely to recorded observations for *P. cryptogea*. In pure culture no oospores developed during one month. Later (10) he reported oospores again in the same mixture. They appeared in the *P. cryptogea* zone only. In mixed cultures with *P. cinnamomi*, *P. richardiae* behaved like *P. cryptogea*, oospores developing in the *P. richardiae* zone.

Ashby (10) obtained oospores in mixed cultures of *P. arecae* and *P. meadii* in 4-5 days. They were in oogonia with amphigynous antheridia and resembled those produced in mixed cultures of *P. palmivora* and in pure cultures of *P. parasitica*. They developed in the *P. meadii* zone but not in the *P. arecae* zone.

Narasimhan (142) in 1930 reported that in mixed cultures of *P. arecae* and an isolation from *Santalum album* oospores developed promptly and freely in the region where the hyphae of the cultures intermingled. In plate cultures in which strips of mica with tiny holes were placed between the mycelia to permit the passage of a limited growth of hyphae and facilitate microscopic examination he reported that the antheridia were produced by *P. arecae* and the oogonial incepts by the Santalum fungus. If substantiated by further observations this evidence demonstrates hybridism or heterothallism. The behavior in mixed cultures of unidentified Phytophthoras from Loranthus and Jathropha indicated that the former could be considered a male strain, like *P. arecae*, and the latter female, like the Santalum isolation. When non-oospore-forming cultures of *P. parasitica* and *P. meadii* were grown in mixed cultures with *P. arecae* and the Loranthus isolation (the male strains) oospores developed, while none appeared when they were grown with the female strains. In explanation he suggested that *P. parasitica* and *P. meadii* had lost their ability to produce oospores through the disappearance of the male strains and that *P. arecae* and the Loranthus strains furnished the necessary antheridia.

The oospores reported in mixed cultures of *P. parasitica* and *P. arecae* were 24-25μ in diameter, and, on account of their size, said to be intermediate between the sizes characteristic of the 2 species, they were considered evidence of hybridization. However, the writer's measurements of oospores of *P. parasitica* in Table 11 show that average diameters of 24-25μ are not uncommon for *P. parasitica*.

Neither does Narasimhan's assumption of heterothallism in *P. parasitica* seem justified. The writer has found mature oospores in 35 of 57 single strain cultures in this species. Some of them produce oospores rarely, but when they do appear they are always in oogonia with amphigynous antheridia. No evidence has been observed that parthenogenic

oospores may develop. Ashby (9) obtained oospores of this species with both *plus* and *minus* strains of *P. palmivora*.

Ashby's (10) report of oospores in mixed cultures of *P. meadii* and *P. arecae* produced in the *P. meadii* zone only, does not give added weight to Narasimhan's report that *P. arecae* produces antheridia only, as it seems reasonable to expect that the hyphae of *P. meadii* would penetrate as deeply into the mycelium of *P. arecae* as the converse, and if heterothallism prevails oogonia and oospores should develop wherever the 2 strains come in contact. Ashby (10) did not observe a preponderance of oospores at the line of union of the mycelia.

The observations reported by Ashby (8) on the development of oospores of *P. cinnamomi* in mixed cultures of *P. parasitica* and *P. cinnamomi* make it necessary, assuming heterothallism, to consider *P. parasitica* the male and *P. cinnamomi* the female strain. Later (9) (10) in mixed cultures of *P. cinnamomi* with *P. cryptogea* and *P. richardiae* he found oospores in the zones of growth of the last two and considered them belonging to those species. Again assuming that heterothallism is the case, it would now be necessary to consider *P. cinnamomi* the male, antheridium-producing strain, while in mixtures with *P. parasitica* it was considered female in character. Since it is not known whether Ashby was using the same single strain culture of *P. cinnamomi* throughout, it may be suggested that he used different strains, one male and the other female. The fact that Ashby (11) and the writer have observed oospores and antheridia in single strain cultures of *P. cinnamomi*, *P. cryptogea* and *P. richardiae* obviates the necessity for assuming that heterothallic strains exist in these species.

Ashby (9) used the early production of oospores in mixed cultures of *P. palmivora* to aid in distinguishing atypical cultures from *P. parasitica*; mixed cultures of the latter with *P. palmivora* produced oospores only after considerable time. Narasimhan (142) obtained them readily in mixed cultures of *P. arecae* and *P. parasitica*. The tendency of mixed cultures of various species to produce oospores does not seem to warrant attaching much importance to this character as a taxonomic criterion pending further investigations on the actual occurrence of heterothallism or hybridism.

The writer has grown a number of isolations of *P. palmivora* in mixed culture and obtained oospores like those reported by Gadd (79) and Ashby (9). Examination of the cultures failed to give any evidence of heterothallism. The amphigynous antheridia developed on separate hyphae from the oogonia but the writer was unable to trace them to different thalli. No trials have been made using the technique described by Narasimhan (142).

TAXONOMY

The Genus

The genus Phytophthora was created in 1876 by de Bary (57) who recognized the longstanding fallacy involved in the identification of the potato blight fungus as a Peronospora. DeBary considered Phytophthora distinct from Peronospora in having not one but several sporangia successively formed at the end of each branch of the tree-like sporangiophore. Our present knowledge of the genera indicates important physiological as well as morphological differences, since most of the Phytophthoras grow luxuriantly as saprophytes on culture media while the Peronosporas are narrowly parasitic.

DeBary devised the name Phytophthora from the Greek *phyton* and *phtheiro* signifying "plant destroyer." The combination was indeed appropriate for *P. infestans*, the species he studied. We now have species attacking all parts of the hosts, leaves, flowers, peduncles, petioles stems, buds, fruits, crowns and roots.

Phytophthora deBary Journ. Bot. 14:105. 1876. "Mycelium in cellulas matricis, quas enecat, haustoriis sparsis vel nullis instructum. Hyphae conidiophorae plerumque parum ramosae. Conidia primo acrogena dein etiam pleurogena, ovata, apice papillata, zoosporipara. Oosporae globosae, episporio subtenui, levi, brunneo tectae".

The above description from Saccardo (186) was amplified by Fischer (77) in 1892 who separated Phytophthora from Pythium on the basis of the methods of formation and liberation of the zoospores. In Phytophthora they are fully differentiated in the sporangium. In Pythium a vesicle appears, into which the contents of the sporangium pass and in which the differentiation of the zoospores occurs. The genus, as delineated by Fischer (77), seems to be firmly established. The recorded differences between Phytophthora and Pythium seem slight, but it is usually possible to distinguish cultures of the two genera macroscopically by small differences in the appearance of the aerial growth of mycelium which in Pythium usually has a whiter, fluffier, and more delicate character than in Phytophthora.

The genus was included in the family Peronosporaceae by deBary (57), and Fischer (77), Schroeter (191) and Berlese (18) retained this arrangement. Pethybridge (156) in 1913 favored the retention of species with paragynous antheridia in the Peronosporaceae as the new genus Nozemia, and the creation of a new family, Phytophthoraceae, for the genus Phytophthora which he proposed to limit to species with amphigynous antheridia. Wilson (238) in 1914 considered the differences between the groups with amphigynous and paragynous antheridia important enough to justify establishing a new order, the Phytophthorales, for

Pethybridge's family, Phytophthoraceae. He suggested that the genus Phloeophthora, founded by Klebahn (110) in 1905 and discarded in 1909 (111), had priority over Nozemia for species with paragynous antheridia. Lafferty and Pethybridge (113) in 1922 announced the presence of occasional amphigynous antheridia in cultures of *P. cactorum*, a member of the Nozemia or Phloeophthora group, and abandoned the genus Nozemia, founded on antheridial characters.

Fitzpatrick (78) in 1923 favored a combination of Phytophthora and Pythium as a single genus. The proposal seems to have been made from a study of the literature and was not favorably received by students of the genera. His recommendation that Pythium, Phytophthora and closely related species be included in the family Pythiaceae, a division of the Peronosporales, seems the most logical scheme of classification. The Peronosporaceae were regarded by Fitzpatrick (78) as distinguishable from the Pythiaceae by their simultaneous development of sporangia, the more definite sporangiophores, the absence of saprophytic tendencies, and the more typically deciduous sporangia. This classification, which places the Pythiaceae in a position rather intermediate between the Saprolegniales and the parasitic Peronosporaceae, was adopted by Dufrenoy (66), Gwynne-Vaughan and Barnes (88), Heald (95) and other writers.

The similarity of Pythiacystis to Phytophthora was observed by Barrett (12), Fawcett (74) and Smith and Smith (201). Leonian (116) in 1925 combined them, the single species of Pythiacystis becoming *Phytophthora citrophthora*.

Miss Buisman (31) in 1927 transferred *Blepharospora cambivora* Petri to Phytophthora. The writer's study of Petri's fungus indicates that the combination of the genera is justified. Miss Buisman also considered *Pythiomorpha gonapodioides* Peter. a Phytophthora. A culture of this fungus received from Baarn failed to produce either sporangia or oospores and soon died. The mycelial development was more like Pythium than Phytophthora, but insufficient data were obtained to determine its relationships.

Sideris (197) in 1929 proposed a division of Phytophthora into 4 sections based on the types of spores developed in culture. It is apparent that such a division would be very artificial and would vary widely with the medium, temperature, and other factors. *P. parasitica* would fall into 2 groups depending upon the presence or absence of oospores in the cultures examined.

Various criteria for the separation of species have been used by investigators of the genus. Rosenbaum (183) in 1917 based his identifications on the type of antheridium and the sizes of the sexual and asexual reproductive organs. The number of cultures studied was small and he

failed to recognize the fact that wide variations in the dimensions of sporangia and chalmydospores occur within a species. For example, *P. palmivora* (*P. faberi*) would lose a majority of the isolations ordinarily referred to it were those producing chlamydospores with a mean diameter of less than 35μ excluded, as they must be if his scheme of classification is followed.

Leonian (116) in 1925 devised a key for the identification of species based on their physiological reactions as evidenced by the formation of reproductive organs in various nutrient media. Morphological differences were usually disregarded as being too variable to have taxonomic significance.

Dufrenoy (66) in 1926 considered differences in the chemical composition of the protoplasm more important taxonomic criteria than morphological differences. Dufrenoy and Dufrenoy (67) in 1927 concluded from a review of the literature that species cannot be identified by their host relationships or by morphological characters on the host or on culture media.

Leonian (118) in 1927 studied the influence of the host on the morphology of the sporangia and found it very marked. He concluded that identifications of species should be made from cultures under carefully controlled conditions rather than directly from the host. Leonian and Geer (119) in 1929 examined the sporangia of numerous isolations produced on sterile mycelium transferred to M/100 potassium nitrate solution. They found considerable variation within species and among strains derived from the same parent culture. They concluded that sporangium size, even under controlled conditions, is of little value in taxonomy. They also considered the size of the oogonia and antheridia, and the type of antheridium of little taxonomic significance; apparently this view was obtained from an examination of the literature rather than experimental study of sexual reproduction in the genus.

Gadd (83) in 1927 believed that the morphology of the sexual organs is the most reliable specific criterion.

Ashby (10) in 1929 observed that several species have a common character in the resumption of growth by the sporangiophores through the bases of evacuated sporangia.

The Species

1. *Phytophthora infestans* (Mont.) de Bary Journ. Roy. Agr. Soc. 2, 12:239. 1876.
   Botrytis infestans Mont. Mem. de l'Inst. 113. 1845.
   Botrytis devastatrix Lib. Rev. Bot. 1: 151. 1845

Botrytis solani Hart. Verhandl. Amsterdam Acad. 12:203-297. 1846.
Botrytis fallax Desm. Crypt. de France I:492. 1846.
Peronospora trifurcata Unger Bot. Zeit. 5:314. 1847.
Peronospora fintelmannii Casp. Verhandl. d. Preuss. Gartenbau-Vereins: 327. 1852.
Peronospora infestans Casp. Rabenh. Herb. Myc. n. 1879. 1854.
Peronospora devastatrix Casp. Ber. Verhandl. Königl. Preuss. Akad. Berlin 308. 1855.

"Hyphis mycelicis gracilibus, haustoriis semper fere destitutis; hyphis conidiophoris tenuibus, sursum sensim attentuatis, sub apice conidiophoro semel vel pluries vesiculoso-inflatis, superne ramos 1-5 sparsos stipitis primarii apici conformes patentesque gerentibus; ramis aut simplicibus aut rarius ramulo brevi munitis (stipes primarius rarissime omnino simplex occurrit); conidiis ellipsoideis vel ovoideis, 27-30x15-20, apice papilla prominente munitis, zoosporas circ. 10 gignentibus; oosporis ignotis.

"Hab. in Solanis, praecipue *S. tuberoso*, in tota Europa et America. Mycelium in tuberibus perennat omnes partes herbaceas invadit totamque plantam destruit. Hyphae conidiophorae praesertim e foliorum pagina inferiore emergunt, caespites latos, albos ibi sistentes. Oosporae ignotae."

Saccardo's (186) above description was compiled from deBary's (57) report. DeBary did not obtain the fungus in culture or find oospores during his extensive investigations (55) (56). Hallier (89) in 1875 obtained sporangia on inoculated plum fruits and Hecke (96) in 1898 grew the fungus in various plant decoctions but obtained no growth on solid media. Matruchot and Molliard (126) in 1903 found a pumpkin infusion solidified with gelatine suitable for growth. Clinton (41) in 1906 reported sterile moist corn meal a satisfactory medium, and later (44) found that oat agar gave the best results in numerous trials of different substrata. Oat agars have been generally employed by the more recent investigators.

The occurrence of oospores in rotted parts of the potato plant was reported by Smith (202) in 1875. DeBary (57) disagreed as to the identity of the bodies observed by Smith. Examination of Smith's (202) (203) (204) drawings indicate that deBary was probably correct. In one case (202) the drawings resemble those of Pythium oospores and in the others (203) (204) the nodose or spiny oospores do not resemble the smooth oospores now known to be typical of the species. Smorawski (205) in 1890 reported oogonia with paragynous antheridia in potato tubers.

Jones (106) and Jones and Giddings (107) in 1909 obtained oogonium-like bodies in pure cultures; no antheridia were observed. Clinton (43) considered these bodies as likely to be chlamydospores as oogonia. Clinton (44) in 1910 reported oogonia, antheridia and oospores in oat agar cultures, and noted that the antheridia and oospores apparently originated on different hyphae. The antheridia resembled those of *P. phascoli* in showing what he considered a superimposed oogonial thread; oospores did not develop in oogonia without antheridia.

Pethybridge (155) in 1912 reported oogonia but no oospores on oat agar, but Pethybridge and Murphy (163) in 1913 obtained oospores abundantly in some strains while others failed to produce them. Numerous oospores in oogonia without antheridia were considered to be parthenogenic. The antheridia, when present, apparently surrounded the lower, funnel-shaped part of the oogonia. Pethybridge (160) in 1914 observed the growth of the oogonial incept through the antheridium which is typical of species with amphigynous antheridia. Lohnis (124) in 1922 reported immature oogonia and oospores in cultures on raw potato tubers. Bruyn (28) in 1923 obtained them on corn meal agar, oat agar, raw potato tuber and probably in soil cultures. Eriksson (68) in 1923 reported oospores in the leaf tissue of potato at the periphery of primary spots, also observations on their germination and the emergence of germ tubes through stomata. Bruyn (29) in 1926 found that oogonia and antheridia developed on sterilized dry, brown plant parts, especially cereal straw, while on the corresponding sterilized fresh green parts growth was poor or absent.

Berg (16) obtained oogonia with amphigynous antheridia in cultures from Australia, England and Holland, but none appeared in his American strains. Murphy (141) in 1927 found oogonia without antheridia, and also oospores in fragments of naturally infected potato tubers. In the soil about a buried inoculated potato tuber numerous similar oogonia were observed. When no antheridia were present the oospores usually failed to develop. Szymanek (211) reported bodies resembling oogonia without antheridia in cultures on sterile soil.

The diameters of oogonia and oospores on agar were recorded by Clinton (44) oogonia 34-50μ (mostly 38-42μ), oospores 24-35μ. Pethybridge and Murphy (163) reported oogonia 31-46μ, average 38μ, and oospores averaging about 30μ in diameter. Murphy (141) reported oogonia 31-43μ, average 36μ and oospores 25-30μ, average 27μ on potato tubers. The writer's No. 248 produced oogonia and oospores averaging 27.9 and 23.6μ respectively.

Sporangia are produced in cultures, and the writer found steamed corn meal favorable to their development. They are fairly constant in size as may be noted by the following records: DeBary (57), on

potato leaves, 27-30x15-20μ; Smorawski (205), on potato tuber tissue, 25-35x15-20μ; Rosenbaum (183), on oat agar, mean 27.08x18.27μ; Haskell (94), on eggplant, 23-35x15-23μ, mean 30x19μ; Siemaszko (198), on tomato fruits, 15-47.8x12-26μ, usually 28.6-36.8x17.7-20.3μ; Vowinckel (231), on *Lycium halmifolium*, 15-34x12-22μ, average 22.9x18μ; on potato leaves, 18-38x13-21μ, average 24.8x18.1μ. Müller (139) studied 12 strains from Germany and Holland and found that the average sizes of sporangia on potato tuber fell within the ranges of 30.14-33.62x19.30-22.13μ. Leonian and Geer (119), on potato, mean 30.08x19.80μ; the writer, on steamed corn meal, obtained average dimensions of 35.58x22.04μ and 37.91x21.88μ for two strains.

P. infestans was used by deBary (57) as the type for the genus Phytophthora. Decaisne (59) in 1846 stated that the potato blight was first attributed to a fungus, *Botrytis farinosa* by Mlle. Libert, who probably did not describe it. Caspary (38) in 1855 recognized differences in sporangiophore characters between *Peronospora infestans* and other Peronosporas and created a new tribe in the genus. Speerschneider (206) in 1857 considered *Fusisporium solani*, which he found common in rotting tubers, a stage of *P. infestans*.

Leonian and Geer (119) included *P. infestans* in a group containing *P. thalictri* and *P. phaseoli*; all failed to grow on malt extract agar in 6 days, exhibited narrow and specialized host relationships and produced small sporangia.

The writer has obtained sporangia in some cultures of other species of a smaller average size than those of *P. infestans*, but the latter is easily identified by its poor growth on most media, e. g. potato dextrose agar and malt extract agar, and its low temperature requirements, growth failing to occur on corn meal agar at 27.5°C. It attacks only hosts in the Solanaceae, a few of which are sometimes classified with the Scrophulariaceae, and is the only species occurring on those hosts which fails to grow readily on potato dextrose agar. The antheridia are amphigynous, but the failure of many strains to develop sexual organs in culture makes the use of this character undesirable, nor is it at all necessary.

2. *Phytophthora cactorum* (L. and C.) Schroet. Krypt. Fl. Schles. 236. 1889.
Peronospora cactorum L. and C. Beitr. biol. pflanz. 1:51. 1870.
Peronospora sempervivi Schenk Bot. Ztg. 33:690. 1875.
Peronospora fagi Hartig Zeitsch. forst. jagdw. 8:117. 1876.
Phytophthora fagi Hartig Bot. Zeit. 37:512. 1879.

Phytophthora omnivora deBary Bot. Ztg. 39:618. 1881.
Phytophthora pini Leon. Amer. Journ. Bot. 12:444. 1925.
Phytophthora citricola Saw. Rept. Dept. Agr. Res. Inst. Formosa 27, 73 pp. 1927.
Phytophthora pini var. antirrhini Sun. and Ram. Mem. Dept. Agr. India 16:83. 1928.
Phytophthora paeoniae Coop. and Port. Phytopath. 18:881. 1928.

"Conidienträger schlaff, dünn; wenig verzweigt. Zweige vor dem Conidienansatz nicht verdickt. Conidien end- oder seitenständig, eiformig, 50-60 (manchmal bis 90)μ lang, 35 (manchmal bis 40)μ breit. Am Scheitel mit einer Papille, im Wasser bis über 50 Schwärmsporen bildend. Oosporen kuglig, meist 24-30μ Dchm. Mit zweischichtiger, gelbbrauner, glatter, nicht sehr dicker Membran."

DeBary's cited description of *P. omnivora* is merely a combination of *P. cactorum*, *P. fagi* and *P. sempervivi* which he recognized as synonymous species. He also recognized the validity of *P. cactorum* as the prior specific name but considered *P. omnivora* the more fitting. Subsequent writers have been divided in their attitudes, some adopting *P. omnivora* and others discarding it. Unfortunately, more recent writers have apparently become confused as to deBary's original intentions and have treated *P. cactorum* and *P. omnivora* as separate and independent species. An examination of deBary's (58) drawings leaves no doubt that the organism he studied was *P. cactorum* as we today know it. *P. omnivora* should therefore, be permitted to remain *synonymous* with *P. cactorum* and should never be used to designate species resembling *P. parasitica*, which produce oospores with much less regularity than *P. cactorum* and amphigynous antheridia instead of the paragynous ones which predominate in *P. cactorum*. Schroeter (190), Thaxter (215), Berlese (18), Saccardo (186), Wilson (237) (238), Lindau (121), Pethybridge (158), Bubak (30) and other writers recognized the validity of *P. cactorum* and relegated *P. omnivora* to synonymy.

Leonian (116) attempted to revive the species as a receptacle for several species with amphigynous antheridia or no sexual organs, which showed similarities in physiological reactions. Leonian and Geer (119) included *P. colocasiae*, *P. faberi*, *P. palmivora*, *P. parasitica*, *P. parasitica var. rhei*, *P. melongenae*, and *P. terrestris* in *P. omnivora*. Several others were considered, possibly, members of the same species: *P. theobromae*, *P. hibernalis*, *P. meadii*, *P. jatrophae*, and *P. allii*. They divided *P. omnivora* into 6 groups based on the type of growth in culture, and the size and shape of the sporangia.

Seal (193) adopted Leonian's classification and considered *P. palmivora*, *P. faberi*, *P. terrestris* and *P. parasitica* synonymous and referred them to *P. omnivora*. Miss Schwarz (192) referred to isolations of *P. palmivora* and *P. parasitica* from orchids in Java as *P. omnivora*.

When Osterwalder (147) (149) and Klebahn (111) referred to *P. omnivora* one may be fairly certain that they used the name as delineated by deBary (58) but the recent uses of it by Seal (193) and Schwarz (192) must be investigated to determine whether they have adopted deBary's usage or are following Leonian (116) in applying it to a group of species, none of which have much in common with the species combined under that name by deBary. Such a condition is very confusing and the writer favors discarding the name *P. omnivora*. Ashby (8) opposed Leonian's combination of species and the use of *P. omnivora*. He stated that, "He (Leonian) has assumed that after *P. Cactorum* and *P. Fagi* were separated from *P. omnivora* a residue remained in which some form referable to one or other of the three first-named species (P. *parasitica*, *P. Faberi* and *P. Colocàsiae*) could be recognized. Until evidence in support of this view can be furnished, *P. omnivora* deBary must be regarded as a synonym of *P. Cactorum*." The evidence obtained by the writer all points toward a complete separation of *P. cactorum* from the species without sexual organs and those with amphigynous antheridia.

P. fagi was considered identical with *P. cactorum* by deBary (58), Saccardo (186), Schroeter (190), Berlese (18), and Leonian (116). Himmelbaur (97) attempted to distinguish it from *P. cactorum* by small differences in the size of the oospores, the location of the antheridia on the oogonia and the occurrence of haustoria. Lafferty and Pethbridge (113) considered *P. fagi* distinct from *P. cactorum* because of its failure to infect some plants which the latter attacked.

The writer's isolation of *P. fagi* (No. 192) was listed with the *P. cactorum* isolations from which it could not be distinguished by growth characters, sporangium size, morphology of the sexual organs or reactions to different temperatures. It proved non-pathogenic to potato tubers which were attacked by other isolations except *P. citricola*, which also will be shown to belong to *P. cactorum*.

P. pini was described by Leonian (116), who observed differences in its physiological reactions to various nutrient media. He reported the antheridia commonly paragynous and usually only one to an oogonium, but amphigynous antheridia were observed and the occasional presence of 2, 3 or 4 antheridia on a single oogonium was reported. The writer's studies of Nos. 149 and 160, probably descended from the same isolation, on ordinary media, have revealed no differences between *P. pini* and *P. cactorum* of sufficient importance to warrant maintaining

P. pini, and Nos. 149 and 160 have been listed in the tables of results as *P. cactorum*. In the temperature studies Nos. 149 and 160 proved faster growers than the other isolations, but the responses to different temperatures were very similar. No differences were found in the morphology of the oogonia and antheridia. The production of sporangia was not abundant but some isolations of *P. cactorum* exhibited equally sparse production. No significant differences were noted in virulence to various inoculated hosts.

P. pini var. antirrhini, described by Sundararaman and Ramakrishnan (209) must be included in *P. cactorum*, since *P. pini* is combined with this species. Its describers distinguish it from *P. cactorum* by its sparsity of sporangia, lack of sphaero-conidia, and smaller oospores. The writer has shown that the first two characters are variable. They reported profusely developed oospores with an average diameter of 26.2μ, which agrees closely with figures reported by the writer. A character which may serve to distinguish the fungus from *P. cactorum* is the size of the sporangia in agar cultures, which was reported as 51.8x39.8μ (average), considerably larger than any averages obtained by the writer. Sporangia borne in water had average dimensions of 30.3x20.2μ. The writer has not examined a culture of Sundararaman and Ramakrishnan's isolation, and its combination with *P. cactorum* is provisional, awaiting further evidence regarding its sporangial and antheridial characters, and its temperature relations. The description (209) indicates that paragynous antheridia predominate. The describers separated it from *P. pini* on account of the absence of intercalary sporangia, the larger sporangia, and the occurrence of only one antheridium on each oogonium. The writer has found the latter character characteristic of both *P. pini* and *P. cactorum* in agar cultures.

P. citricola was described by Sawada (189). Mr. S. F. Ashby has kindly furnished a translation of the description. A culture of the species (No. 267), in the writer's hands produced abundant oogonia with paragynous antheridia and oospores indistinguishable from those of *P. cactorum*. Sporangia were developed rather sparsely and the papillae were not very conspicuous. It proved nonpathogenic to potato tubers, like No. 192, while the other isolations of *P. cactorum* caused a rot. In growth characters and temperature relations it proved typical of *P. cactorum*. Sawada (189) reported sporangia with a mean size of 43.3x25.3μ, but the writer obtained an average of 32.3x25.6μ, very similar to the size of the sporangia of *P. cactorum*. Sawada (189) apparently considered *P. citricola* closely related to *P. syringae*, but a comparison of the temperature relations shows that *P. citricola*, behaves like *P. cactorum* and grows at temperatures which *P. syringae* does not tolerate. *P. citricola* is clearly referable to *P. cactorum*.

P. paeoniae, represented in the writer's collection by No. 243, received from M. W. Gardner, has been included with *P. cactorum* in the results of the investigations. It has proven impossible to separate it from the other isolations of this species. Cooper and Porter (48) created *P. paeoniae* on the occurrence of the oogonia and antheridia on long, twisting branches, the less elongated and more prominently papillate sporangia, and the failure of *P. cactorum* from other hosts to infect peonies. In the writer's cultures the peony fungus has not differed from *P. cactorum* in the type of oogonial and antheridial stalks. The sporangia were no shorter than those of Nos. 196, 194, 184 and 172. The failure of *P. cactorum* to infect peonies suggests the existence of biologic strains and agrees with the variations in pathogenicity commonly found by the writer in various species. Beach (14) reported an apple strain less virulent on rhubarb than his rhubarb strains.

The size of the sporangia was reported by Lebert and Cohn (114), on *Cactus spp.* as 35-68μ long (ave. 48μ); Hartig (91), on beech leaves, about 40x25μ; Osterwalder (147), on apple fruits, 17-120x14-25μ; Hori (99) on ginseng tissues, 50-60x30-50μ; Osterwalder (148) on *Calceolaria sp.* stems, 14-50μ long; Bubak (30), on pear fruits, 15-120x15-25μ; Himmelbaur (97), on media, 30-40x15-30μ; Osterwalder (149) on apple bark, 23-61x32μ or less; Rosenbaum (182), on media, average 34.5x27μ, and later (183), on media, average for 3 strains, 35.95x25.82μ; Wormald (240), on pear fruits, 35-65x22-35μ; Thurston and Orton (220), on media, 20.4-29.7x16.7-22.3μ; Beach (14), on media, average for 4 strains, 34.4x25.4μ; Lafferty and Pethybridge (113), average for 3 strains, on media, 37x27μ, on apple fruits, 52x30μ; Rose (179), on media, average 32.26x25.09μ; Rose and Lindegren (180), on media, average 34.4x26.8μ, on apple and pear fruits, average 40.3x26.9μ; Drechsler (61), on media, average for 2 strains, 35.3x27.6μ; and Leonian and Geer (119), in M/100 potassium nitrate solution, average for 4 strains, 36.23x29.29μ. The writer (Table IV) obtained averages of 30.39x22.77μ for 10 strains.

The size of the sporangia produced on host tissues is widely variable. On culture media less variation occurs. In Table III it may be noted that the average dimensions for 10 strains fall within the extremes 26.05-34.07x20.71-25.72μ. This indicates considerable stability when compared with the variations that occur in *P. palmivora* and *P. parasitica*.

The presence of sphaero-conidia, chlamydospores or unfertilized oogonia in cultures is a variable character. They were reported by Smith and Smith (201) and Rose (179) in old potato dextrose agar cultures. The writer found this medium less satisfactory for oospore maturation than the others used. Cooper and Porter (48) found a few chlamydospores in cultures on cooked peony stems. The writer has found these

bodies in varying abundance in most of the cultures examined. They are easily distinguishable from the chlamydospores produced by *P. palmivora* and other species by their thinner walls and by their failure to become darker in color than the sporangia. It has been mentioned that the presence of occasional antheridia indicates that they are possibly oogonia in which the oosphere failed to develop into an oospore, probably through non-fertilization.

The oogonia are pyriform or subspherical, usually with a broadly funnel-shaped base. The oospore fills most of the interior. The oospores are straw-yellow to almost colorless; smooth and thick-walled. The antheridia are usually paragynous (Figs. 4 and 5). A few writers have reported occasional amphigynous ones, but the paragynous type predominates by a vast majority. Oogonia and oospores are borne profusely on most ordinary media, and observations on the type of antheridium and size of oogonia and oospores are numerous; some of them are as follows: Lebert and Cohn (114) in *Cactus spp.*, paragynous, oospores average 24μ; Hartig (91) (92) in *Fagus sp.*, paragynous, oogonia about 20μ; Hori (99), in ginseng tissues, oospores 26-28μ; Osterwalder (149), in apple bark, oogonia 23-33μ; Clinton (44), on media, oogonia 20-35μ, oospores 18-28μ; Himmelbaur (97), on media, oospores of beech strain 20-30μ, oospores of Cactus strain 30-45μ; Rosenbaum (183), paragynous, on media, mean oospore diameter for 3 strains 28.12μ; Wormald (240), on pear fruits, oospores 22-30μ; Clinton (45), on media, oogonia 24-36μ, oospores 21-32μ; Beach (14), on media, oospores of 3 strains average 26.3μ; Lafferty and Pethybridge (113), on media paragynous and sometimes amphigynous antheridia; Rose (179), on media, paragynous and rarely amphigynous, oospores 14-35μ (mean 26.42μ); Rose and Lindegren (180), on media, paragynous and sometimes amphigynous, oospores 15-43μ (average 26.6μ); Smith and Smith (201), on media, paragynous or occasionally amphigynous, oospores of almond strain 30-40μ; of peach strain 28-34μ, of black walnut strain 25-30μ; and Drechsler (61), on media, oospores of 2 strains average 26.7μ. The writer (Table 11) found that the average diameters of the oogonia of different isolations varied from 26.8 to 29.4μ, and of the oospores from 24.2 to 26.5μ. The averages include oogonia and oospores produced on different media.

The antheridia were nearly always paragynous, but usually attached near the base of the oogonium (Figs. 4 and 5). Cases in which the oogonium appeared to have penetrated the antheridium were very rare.

P. cactorum may be identified by its profuse production of oogonia with paragynous antheridia, the absence of typical chlamydospores, the small and often inconspicuously papillate sporangia, and by its growth on corn meal agar at 27.5°C. (Figs. 4 and 5). The only other species with

predominantly paragynous antheridia is *P. syringae*, which does not grow at 27.5°C.

3. *Phytophthora phaseoli* Thaxter Bot. Gaz. 14:273. 1889.

"Mycelial hyphae branched, rarely penetrating the cells of the host by irregular haustoria. Conidiophores slightly swollen at their point of exit though the stomata, arising singly or one to several in a cluster; simple or once dichotomously branched, and once to several times successively inflated below their apices. Conidia oval or elliptical, with truncate base and papillate apex; 35-50x20-24μ. Germination by zoospores, usually 15 in number, or rarely by a simple hypha of germination. Oospores unknown.

"On pods, stems and leaves of Lima bean (*P. lunatus*) New Haven, Conn. Sept. and Oct."

Clinton (42) in 1906 found oogonia and oospores and emended Thaxter's above description as follows:

"Oogonia inter- or intracellular in seed coats or cotyledons of seeds, occasionally in tissues of pods and more rarely imbedded in mycelium on surface of seeds and pods, with rather thin, scarcely folded walls loosely enclosing oospore, at first hyaline or slightly tinted but finally reddish brown, subspherical, chiefly 23-38μ in diameter. Oospores spherical or sometimes subspherical with apparently smooth and moderately thick walls (2.5-4μ, chiefly 3μ in thickness), hyaline or light yellowish, 18-26μ, chiefly 19.5-22.5μ in diameter. Antheridia temporary, hyaline, variable, sometimes irregular but chiefly ovoid to ovate, usually applied to oogonia near their place of attachment to the mycelium, chiefly 8.5-11.5μ in width by 14-17μ in length."

Clinton (42) observed that antheridia and oogonia arose on different hyphae, and, in 1908 (43) stated that, "The oogonial thread, with or without a swelling, becomes attached to the base of the antheridium and grows up along its surface toward the apex. . . . .For a long time it was difficult to decide whether or not these threads did not actually penetrate the antheridium and grow through it, and we are not yet certain that this does not sometimes occur." Pethybridge (160) in 1914 observed the development of the sexual spores and reported that the oogonial incept does penetrate and grow through the antheridium in the manner typical of species with amphigynous antheridia.

Clinton (42) in 1906 obtained *P. phaseoli* in pure culture where it grew sparsely and produced sporangia and oospores. Later (43) (44) he reported good growth and abundant oospores on lima bean agar and oat agar. Rosenbaum (183) and Leonian (116) reported profuse production of oogonia and oospores in oat agar cultures. Leonian and Geer (119) in 1929 failed to obtain growth on malt extract agar in 6 days.

Clinton (44) reported oogonia on oat agar 24-34μ (average 29μ) in diameter, and oospores 18-26μ (average 22.5μ); Rosenbaum (183) on the same medium reported oospores with a mean diameter of 25.55μ. He also obtained sporangia with mean dimensions of 27.87x19.05μ; Leonian and Geer (119), on the host, found the mean dimensions to be 34.81x20.09μ.

Thaxter (214) considered the sporangia larger and the sporangiophores different in appearance and manner of branching from those of *P. infestans*; later (215), he observed that the sporangia were smaller than in *P. cactorum*. Clinton (42) considered *P. phaseoli* most nearly related to *P. nicotianae*. Leonian (116) in 1925 made *P. phaseoli* a variety of *P. infestans*, *P. infestans var. phaseoli*, which he could distinguish from *P. infestans* by its abundant development of oogonia on oatmeal agar. Leonian and Geer (119) in 1929 referred to *P. phaseoli*, apparently restoring it to specific rank.

P. phaseoli resembles *P. infestans* and *P. thalictri* in growing slowly on culture media, and in failing to grow readily on potato dextrose and malt extract agars. Its temperature relationships were not determineds but Halsted's (90) observations on its development on lima bean pod after the plants were killed by frost indicates that it has a low optimum like *P. infestans*. It is highly specialized in its host relations, and is known to attack only *Phaseolus lunatus*. Unlike *P. infestans* the lima bean fungus produces oospores regularly, promptly and abundantly on oat agars while the former produces them rather sparsely and only after considerable time, and many strains fail to produce them at all.

The retention of *P. phaseoli* as a distinct species seems advisable.

4. *Phytophthora colocasiae* Rac. Parasit. Algen u. Pilze Javas 1:9. 1900.
   Kawakamia colocasiae (Rac.) Saw. Spec. Repts. Formosa Agr. Exp. Sta. 1911.

"Auf den Blättern der *Colocasia esculenta*, auf ganz Java verbreitet, ohne bedeutenden Schaden zu verursachen. Ist ebenso in der warmen Ebene (z. B. bei Klaten), wie in der Hügelzone bei Soekaboemi und Buitenzorg vorhanden.

"Die unseptirten 3-4μ dicken Hyphen wuchern zwischen und in den Parenchymzellen der Blätter regelmässig radiär, und ohne durch die Nerven beschränkt zu werden. Dadurch entstehen braune, in Centrum vertrocknende Flecken von 1 cm. bis 1 dm. Breite, welche deutliche ringförmige Zonen zeigen. An der Ober und Unterseite der Blätter sind schon mit blossem Auge weisse Punkte sichtbar, die Sporangien des Pilzes.

"Die Sporangien tragenden Hyphen ragen nur äusserst wenig über die Spaltöffnungen, aus welchen sie heraustreten hervor, schwellen an der Spitze bedeutend an und grenzen da, durch eine Querwand ein Sporangium ab, welches gewöhnlich länglich eiförmig, manchmal ein wenig eingeschnürt, beiderseits abgerundet, sehr regelmässig und ziemlich dickwandig erscheint. An der Spitze ist die Sporangiummembran sehr stark verdickt, indem an die eigentliche Wand immer noch ein quellbarer Pfropf eingelargert wird. Bei der Reife fallen die Sporangien, zusammen mit kurzen Stielchen ab; in Wasser gelegt bilden in dem Inneren eine grössere Anzahl Schwärmsporen, welche, in dem der erwahnte Pfropf an der Spitze gelöst wird, nach aussen treten nierenförmig werden und 2 Cilien besitzen. In Wasser kommen sie bald zur Ruhe und keimen, ein secundäres, kleines Sporangium bildend, welches an der Spitze durchwachsen kann, oder gleich 1-2 neue Schwärmsporen bildet. Oosporen nicht beobachtet. Die Sporangien (ohne Stielchen) 48-55μ lang, 19-22μ breit, die Stielchen 3-7μ lang, die Schwärmsporen 15-18μ lang, 9-12μ breit."

Raciborski (172) considered *P. colocasiae* more like *P. phaseoli* than *P. nicotianae* or *P. cactorum* principally on account of similarity in the sporangial dimensions. Butler and Kulkarni (36) in 1913 observed oogonia with amphigynous antheridia in cultures on French bean agar, and Pethybridge (160) in 1914 observed the development of the sexual bodies and the penetration of the antheridia by the oogonial incepts as in *P. phaseoli* and other species. Rutgers (185) in 1917 distinguished *P. colocasiae* from other species by its large sporangia. Leonian (116) in 1925 included it in his *P. omnivora* (colocasiae group), but Ashby (8) in 1928 reported *P. colocasiae* distinguishable from *P. parasitica* by its production of narrowly, as well as broadly ovate sporangia which fall away from the sporangiophores with a pedicel and by its larger zoospores. He separated it from *P. palmivora* by its ready development of oospores in pure culture. On these grounds Ashby (8) opposed Leonian's (116) combination of the 3 species in *P. omnivora*.

Butler and Kulkarni (36) reported sporangia on the leaves of the host 38-60x18-26μ, chlamydospores in cultures up to 30μ in diameter, and oogonia in French bean agar cultures 24-35μ (average 29.5μ), containing oospores 20-28μ (average 23μ) in diameter. Gomez (87) reported sporangia 38-67x17-28μ (average 59x23μ), chlamydospores 17-39μ (average 27μ), and oospores in lima bean agar cultures. Thompson (218) reported that an isolation from *Piper betle* in Malaya identified by Ashby (8), produced oospores in culture at Kew, England, which varied from 19 to 31.5μ (average 23.6μ) on oat, maize and bean agars. The same isolation (Thompson) (219) produced sporangia which averaged 42.78 x26.57μ on maize and oatmeal agars, and chlamydospores with an aver-

age diameter of 24.45μ in maize agar cultures. Leonian and Geer (119) obtained sporangia with mean dimensions of 37.70x24.05μ on mycelium transferred to M/100 potassium nitrate solution.

The writer has examined two isolations, Nos. 152 and 239. In cultures on steamed corn meal 2 weeks old sporangia were abundant and averaged 36.97x21.18μ and 34.24x22.71μ. Chlamydospores were not developed abundantly in the cultures. The few measured averaged about 30μ in diameter. Oogonia with amphigynous antheridia were present in cultures 2 weeks old on oatmeal agar. The oogonia of No. 152 averaged 29.1μ and the oospores 25μ, while those of No. 239 averaged 29.3μ and 24.7μ respectively. Both isolations were practically non-pathogenic in all the inoculation experiments. They proved unusual in failing to grow in apple fruits, as the isolations of other species resembling *P. colocasiae* morphologically, invaded the inoculated fruits readily. Butler and Kulkarni (36) failed to demonstrate the pathogenicity of the species to any of numerous hosts of *P. parasitica* and *P. palmivora* which they inoculated. Gomez (87) was unable to demonstrate another host and *P. colocasiae* was long considered a very narrowly parasitic species. Recently, however, Thompson (218) has isolated it from *Piper betle*.

The temperature relations of *P. colocasiae* serve as a means of distinguishing it from *P. parasitica*; the latter grew at 35°C. while *P. colocasiae* not only failed to develop at 35°C., but was usually killed by an exposure of 96 hours at that temperature. As Ashby (8) has noted, it may be distinguished from *P. palmivora* by the ready production of oospores in pure culture, and, since the inoculation experiments offer additional evidence that the species is distinct from *P. palmivora* and *P. parasitica*, its retention is considered justified.

5. *Phytophthora citrophthora* (Sm. and Sm.) Leonian Amer. Journ. 12:444. 1925.
Pythiacystis citrophthora Sm. and Sm. Bot. Gaz. 42:215. 1906.

"Parasitic on lemons, and occasionally other Citrus fruits, causing decay of green fruit on the tree and in the storehouse. Mycelium in affected fruit sterile, inhabiting rind and fibrous portions. Internal, except in moist air. Mycelium in water or nutrient liquids very vigorous, usually sterile, or occasionally with conidia or sporangia. Fruiting stage found typically in moist soil, in contact with affected fruit. Sporangia ovate or lemon-shaped, sometimes rounded, considerably elongated, or double, with terminal protuberance; 20x30μ to 60x90μ, ave. 35x50μ. Produced in great abundance under favorable conditions. In water dividing quickly by internal division into 5 to 40 (usually about 30) swarmspores, which are immediately set free and discharged through a terminal pore.

"Swarmspores 10 to 16μ in diameter, at first elongated, becoming rounded; with two distinct lateral cilia 30 to 40 μ in length. Actively motile when discharged, soon coming to rest and germinating."

Leonian's (116) transfer of this fungus from Pythiacystis to Phytyphthora was certainly justified. The above original description (200) was accompanied by notes comparing the newly created genus with Pythium and Pythiopsis, but no mention was made of a comparison with Phytophthora. The generic and specific descriptions contain nothing to warrant the separation of the fungus as a new genus. Leonian's (116) combination of the species with others into *P. omnivora* does not seem to be warranted, as *P. citrophthora* exhibits certain characters by which it may be distinguished from *P. colocasiae*, *P. parasitica* and other species which Leonian (116) proposed to lump together as *P. omnivora*.

Smith and Smith (200) reported sporangia, probably on fruits, with average dimensions of 50x35μ; Leonian and Geer (119) reported a mean of 49.17x30.96μ for sporangia borne in M/100 potassium nitrate solution. The writer has found sporangium production on agars rather scanty, as reported by Smith and Smith (201); No. 222 produced them in fair numbers, with average dimensions of 37.70x23.55μ. Nos. 154 and 221 produced sporangia in fewer numbers which averaged 36.1x 24.3μ and 34.6x25.1μ respectively. They fall away with a pedicel.

Smith and Smith (201) reported that no chlamydospores ever developed in cultures, but the writer has obtained them, usually in abundance, in old agar cultures. Those produced by the 3 isolations were very similar in average diameters, which were 28.39μ, 28.06μ and 27.55μ. No oogonia were found by the writer, nor have they been reported for the species.

The isolations were very similar in pathogenicity and were markedly virulent to inoculated tender grapefruit twigs. The data show that the 3 isolations are very similar in respect to the morphology of sporangia and chlamydospores and in pathogenicity, but they do not reveal any character by which *P. citrophthora* may be separated from *P. palmivora*, some strains of which produce sporangia sparingly, and both sporangia and chlamydospores which do not differ much in size or form from those of *P. citrophthora*. The presence of a pedicel on fallen sporangia is another common character of both species.

Examination of the temperature relations (Table 24) shows Nos. 154, 221 and 222 grew less rapidly at 30°C. than at 27.5° and 25°C., and no growth occurred at 32.5°C. All 3 made some growth at 5°C. *P. palmivora* characteristically developed at 32.5°C. but not at 5°C., and grew most rapidly at 27.5° and 30°C. The differences in response to temperature are not large, but the constant behavior of the isola-

tions of *P. citrophthora* indicate that the species cannot be considered identical with *P. palmivora*. A comparison of the behavior of 4 isolations of *P. palmivora* from Citrus (Nos. 180, 249, 250 and 265) with the 3 isolations of *P. citrophthora* reveal no similarities that indicate a closer relationship between the two groups than between the 2 species in general. The differences in the abilities of the groups to grow at 32.5°C. and 5°C., the optimum growth of *P. citrophthora* at 25-27.5°C. and of *P. palmivora* at 27.5°-30°C. indicate essential differences in the protoplasm of sufficient importance to justify the maintenance of *P. citrophthora* as a species.

It is very probable that Phytophthoras isolated from Citrus in various regions have been referred to *P. citrophthora* when a more careful examination would identify them as *P. palmivora*. The writer has examined isolations from Porto Rico, Australia, Formosa, and the Philippines without finding one which agreed with the California fungus.

Since *P. cactorum* has been isolated in California from diseased tissues similar to those which *P. citrophthora* frequently causes, the similarities in temperature responses in the 2 species may suggest that *P. citrophthora* is a non-oospore producing form of *P. cactorum*. However, the species vary widely in the type of growth on corn meal agar, *P. cactorum* producing a matted growth with no distinct tendency toward a radial disposition of the hyphae (Fig. 26) and aerial growth which is rather thick and short; *P. citrophthora* produces a beautifully radiate growth with few or no aerial hyphae (Fig. 28). The species also differ in pathogenicity and in sporangium size and shape.

P. citrophthora may be recognized by its rapid growth on potato dextrose agar, papillate sporangia, failure to produce oospores in culture, inability to grow at 35°C., and its optimum growth on corn meal agar at 25°-27.5°C.

6. *Phytophthora thalictri* Wilson and Davis Bull. Torr. Bot. Cl. 34:387. 1907.

"Hypophyllous, the infected area suborbicular or irregular in outline, appearing somewhat glaucous; epiphyllous discoloration very dark, almost black, sometimes with a distinct brownish margin; conidiophores fasciculate from the stomata, continuous, lax and somewhat flexuose, rather scattered on the infected area and not forming a dense felt, 300-400x5-7μ, bearing usually 1 or 2 branches, subconidial swellings narrowly conical, less than twice as thick as the branch; conidia elliptic, apically papillate, 20-27x13-17μ; oospores unknown.

"Type collected by Dr. J. J. Davis, June 20, 1907, in Kenosha Co., Wis., on *Thalictrum purpurascens* L."

Wilson (237) separated *P. thalictri* from *P. infestans* principally by its slightly smaller and more elongate sporangia.

Clinton (43) in 1908 reported the species producing oospores on *Thalictrum polyganum* and described the oogonia as chiefly subspherical, with moderately thin, reddish brown tinted walls, loosely enveloping the oospore, 25-33μ in diameter. Oospores spherical, hyaline or slightly yellowish, with medium thick and smooth wall (3-4μ), varying from 18.5 to 25μ in diameter.

Leonian and Geer (119) reported the mean size of sporangia on *Thalictrum sp.* 20.60x15.76μ.

Clinton (43) was unable to isolate the species and Leonian and Geer (119) reported no growth on malt extract agar in 6 days. Their conclusion that *P. thalictri*, *P. infestans* and *P. phaseoli* are members of a group characterized by its poor growth on most media and by highly specialized parasitism is helpful in identifying the species. *P. thalictri* has not been recorded on a host outside the genus Thalictrum, nor has any other species been reported on that genus. The writer has not examined the species; the literature indicates that it may be identified by its host relationships, pending further knowledge of the antheridia, temperature relations, etc.

7. *Phytophthora palmivora* Butler Mem. Dept. Agr. India, Bot. Ser., 1:1. 1907.
   Pythium palmivora Butl. Mem. Dept. Agr. India, Bot. Ser., 1:1. 1907.
   Phytophthora faberi Maubl. Agr. Prot. Pays Chauds 9:314. 1909.
   Phytophthora theobromae Colem. Dept. Agr. Mysore, Myc. Ser. Bull. 2. 1910.
   Phytophthora omnivora var. arecae Colem. Dept. Agr. Mysore, Myc. Ser. Bull. 2. 1910.
   Phytophthora arecae (Colem.) Pethyb. Sci. Proc. Roy. Dublin Soc. n. s. 13:529. 1913.
   Kawakamia carica Hara Nogyokoku 9, 3:24. 1915.
   Phytophthora fici Hori Byochu-gai Zasshi 2, 11:930. 1915.
   Phytophthora carica (Hara) Hori Byochu-gai Zasshi 2, 12:1015. 1915.
   Phytophthora carica Hara K. Hara's Kwaju Byogairon:431. 1916.
   Phytophthora meadii McRae Journ. Bombay Nat. Hist. Soc. 25:760. 1918.

"This species is the cause of a very destructive palm disease, which has recently broken out in the Godavery Delta, on the East Coast of the

Indian Peninsula. It attacks the leaf sheaths, penetrating them until the apical bud is reached, when it may also extend to the upper part of the stem. The mycelium is intercellular, only haustoria passing into the cells. This is the only instance of the sort known in the genus. The hyphae are large, often irregularly swollen, up to 7μ in diameter and ramify between the cells of the parenchyma, never penetrating the fibrovascular bundles. Branched finger-shaped haustoria enter the cells, which are rapidly killed and turned brown, the mode of attack resembling that of Phytophthora. Brown, dry, sunken spots are at first formed, but these rapidly undergo a wet rot, due to the entry of putrefying organisms. The spots underlie each other on the successive leaf sheaths, tracing the progress of the fungus from the exterior into the bud. In the softer layers inside, extension is usually more rapid than on the other sheaths, and here the fungus reaches its greatest development. After ramifying through the tissues of the sheaths, it comes out on their surfaces to fructify, forming large white mycelial felts on the inner surfaces of the sheaths. In these, sporangia are formed in the web, not raised on special sporangiophores. The sporangia are Phytophthora-like, inverted pear-shaped or more rarely, round, and always terminal. They germinate readily in water, giving rise to rather large zoospores, formed in the manner typical of Pythium. The sporangia measure 50x35μ, on an average (extremes 38-72x33-42), and the zoospores, after coming to rest, 8 to 10μ.

"In some of the mycelial webs large numbers of thick-walled oospores were found, always extra-matrical. Their development was not seen, and an oogonial wall could not be made out, possibly because the spore may have completely filled the oogonium. The origin and nature of the antheridia could not be determined with certainty, but some cases were seen where the antheridium appeared to arise from a neighbouring branch, and to coil round the oogonium. The oospores are spherical, measuring 35-45μ in diameter, the walls being up to 4μ thick. They germinate readily, giving rise to a short branch on which sporangia are early formed."

Shaw (195) in 1915 studied the fungus in pure culture and considered it probably a Phytophthora.

Butler's (32) original description quoted above identified the fungus as a Pythium, although he noted the marked similarity to Phytophthora. His sole point of differentiation was the liberation of undifferentiated zoospores into a bladder. He later (35) stated that his fungus is a Phytophthora and that the bodies originally described as oospores were chlamydospores. In his original studies he did not study zoospore formation from pure cultures and it is possible that his observation of the

Pythium type of zoospore formation was due to the actual presence of that genus in his material. The subsequent evidence that his fungus was really a Phytophthora is quite convincing, and, as he pointed out in 1921 (34), *P. palmivora* has priority over *P. faberi*.

Ashby (9) in 1929 emended the species description as follows: "As emended to include characters shown in cultures it is an omnivorous tropical species of wide distribution, existing as a number of morphologically, and in some instances, pathologically distinguishable strains. On such standard media as bean-meal, quaker oats, and maize-meal agars typical cultures spread rapidly (optimum for growth 27-28°C.) giving rise to a moderate aerial mycelium of sparingly branched hyphae 4-8μ in diameter and forming, in less than a week at a mean temperature near 25°C., abundant large terminal prominently papillate sporangia in well-developed sympodia: the sporangia when mature fall away from the sporangiophores by natural abscission with a short, often stout and more or less occluded pedicel. In water ten to forty or more zoospores are discharged depending on the size of the sporangium: in cultures on the standard media, sporangia have a mean length between 40 and 60μ and a mean breadth between 25 and 35μ with a mean ratio between 1.4 and 2.0, but are frequently appreciably smaller on the natural substrata. Spherical and subspherical chlamydospores, terminal or intercalated, which do not separate by natural abscission (resting conidia, sphaeroconidia) also form quickly and abundantly (especially on oat and maize media); they have thin or thick, hyaline or brown walls and granular contents and germinate by hyphae; in mean size they range from 32 to 42μ. In atypical cultures formation of sporangia may be more or less suppressed but chlamydospores are developed freely, when young mycelium from either typical or atypical cultures is brought into water, sporangia are usually formed freely in sympodia at temperatures between 20° and 30°C. in two or three days. Sexual spores have not been recorded hitherto in single strain cultures and in only one instance on the host (the coconut in Jamaica). Amphigynous sexual organs with oospores having a mean diameter between 22 and 24μ are, however, formed freely within a week on maize-meal agar at moderate temperatures (20-25°C.) when suitable strains are grown together in pairs. The strains can be divided into two groups conveniently named the "cacao" and "rubber" groups on the basis of this behavior; oospores are formed within a few days when a member of one group is grown with a member of the other but have not been detected after three to six months when two members of one group are grown together. This reaction if it occurs promptly can be used as a means of identifying a new isolation if it has not been found to form oospores in pure culture."

P. faberi was described by Maublanc (127) in 1909 from material and data obtained by von Faber (69) in Kamerun. Like Butler (32), Maublanc (127) erred in identifying the chlamydospores as oogonia and oospores. There are no differences by which *P. faberi* can be separated from *P. palmivora*, except, possibly the pathogenicity of *P. faberi* to cacao, but this is characteristic, usually, of only those strains isolated from cacao. It was customary to consider isolations from cacao *P. faberi* and those from palms *P. palmivora*, while the identification of isolations from other hosts depended upon the personal preference of the investigator.

Petch (153) in 1910 stated that the "oospores' of the cacao fungus were probably chlamydospores. Reinking (177) considered his isolations of *P. faberi* distinct from *P. palmivora* because they did not produce oospores, a distinction which is not valid. Gadd (79) in 1924 concluded that *P. faberi* and *P. palmivora* are very similar, but (83) wished to retain *P. faberi* for the cacao strains and *P. palmivora* for the palm strains. Butler (35) considered them identical morphologically. Leonian (116) reported them alike in behavior in his physiological studies. Lester-Smith (120), Seal (193) Ashby (9), Thompson (219) and other writers regarded the two species as identical and the majority recognized the validity of *P. palmivora* as the specific name.

P. theobromae was described by Coleman (46), who like Butler (32) and Maublanc (127) mistook chlamydospores for oogonia and oospores. Upon learning of Maublanc's (127) description of *P. faberi*, Coleman (46) recognized that the species were synonymous, and they have been so regarded by Lafferty and Pethybridge (113), Ashby (9), Leonian and Geer (119) and others.

P. carica and the synonyms listed by Tanaka (213) in a translation of Sawada's work, are included in *P. palmivora*. No cultures have been available, but Hori's descriptions of sporangia and chlamydospores and the absence of oospores seem to justify the combination on morphological grounds.

There remain for consideration *P. arecae* and *P. meadii*. The Areca fungus was identified, doubtfully, by Sydow and Butler (210) in 1907 as *P. omnivora*. Coleman (46) in 1910 described it as *P. omnivora var. arecae*. Pethybridge (156) in 1913 recognized that the fungus was quite different from deBary's *P. omnivora* and suggested that it be regarded as *P. arecae*. Gadd (83) distinguished *P. arecae* from *P. palmivora* (*P. faberi*) only by the production of oospores by the former and believed that non-oospore-producing strains should be classified as *P. palmivora*. Rosenbaum (181) regarded *P. arecae* and *P. erythroseptica* as very similar or identical since both caused a pink rot of potato tubers. The writer has shown that this is characteristic of other species also.

P. arecae, according to Coleman (46), produced oogonia with amphigynous antheridia and oospores on inoculated Areca fruits, but did not produce them in culture, or in nature on the host. *P. palmivora* fails to produce oogonia in pure culture, but Ashby (5) reported them in a leaf base of a coconut palm in Jamaica. Rosenbaum (183) in 1917 reported amphigynous antheridia, oogonia and oospores in oat agar cultures, but others, Sundararaman and Ramakrishnan (208), Gadd (83), Ashby (8) and Narasimhan (142), failed to obtain them in pure cultures.

P. meadii was described by McRae (132) in 1918; he considered it identical with a fungus from Hevea fruits studied by Dastur (53). McRae (132) reported oogonia with amphigynous antheridia in and on Hevea fruits and in agar cultures. His measurements of oospores agree closely with those reported by Coleman (46) for *P. arecae* and by various writers for those produced in mixed cultures of *P. palmivora*. As in the case of *P. arecae* the production of oospores by *P. meadii* seems to be rare, since Dastur (53) and Sharples, Norris and others (194) failed to obtain them. Ashby (10) reported a few oogonia in old cultures, but in mixed cultures of *P. meadii* and *P. arecae* oogonia appeared in 4-5 days on corn meal agar. Their distribution in the growth zone of *P. meadii* indicated that they were produced by that species. Ashby (10) considered *P. meadii* and *P. arecae* very similar and, possibly, the same species.

Dastur (53) in 1916 distinguished the Hevea black stripe fungus (*P. meadii*) from *P. palmivora* (*P. faberi*) largely by differences in pathogenicity. Gadd (79) (83) found non-oospore producing strains of *P. meadii* indistinguishable from *P. palmivora*. Ashby (8) stated that the sporangia of *P. meadii* resemble, superficially, those of some strains of *P. palmivora* but appear later and less abundantly in cultures. He also considered the production of oospores in pure cultures of *P. meadii* a criterion for their separation, but the rarity of their development makes it of questionable value.

To facilitate a comparison of some of the recorded data on the asexual reproductive bodies of *P. palmivora*, *P. meadii* and *P. arecae* the data are tabulated as follows:

P. palmivora (including *P. faberi*)

Author	Source	Substratum	Sporangia (micra)	Chlamydospores (micra)
Butler (32)	Borassus	Borassus tissues	38-72x33-42 av. 50x35	35-45
Peters (154)	Hevea	Hevea fruits	27-41x20-34 av. 38x26	17-48 av. 36
Peters (154)	Hevea	media	34-44x24-30 av. 39x28	

Author	Substratum	Sporangia		Chlamydospores
Rosenbaum (183)	cacao	oat agar	mean 48.52x 32.29	mean 38.98
Reinking (176)	coconut	corn meal	27-69x21-41	(oatmeal agar) 15.5-57.49 Mean about 39
Reinking (177)	coconut	oatmeal agar	av. 52.27x 31.28	av. 41.62
Reinking (177)	cacao	oatmeal agar	av. 51.92x 30.67	av. 41.06
Ashby (5)	coconut	lima bean agar	usually 45-50x29-32	30-41. Mean about 37
Ashby (5)	coconut	coconut tissues	av. 45x29	19-52. Mean about 29-33
Maublanc (128)	cacao	cacao fruits	30-65x20-53 av. 50x30	30-60
Gadd (79)		Corn meal agar	av. for 7 isolations 49x29	av. for 7 isolations 37
Thompson (216)	Piper	corn meal agar	av. 41.99x27.25	18-33 av. 24.45
Thompson (219)	Hevea		av. on 3 agar media 52.3x30.9	av. on 3 agar media 35.5
Ocfemia and Roldan (146)	Citrus	media	av. 44.7x29.4	av. 31
Schwarz (192)	Vanda	oat malt agar	av. 48x33.5	
Schwarz (192)	Cattleya	oat malt agar	av. for 2 isolations 55x34.2	
Tucker (227)	Sabal	corn meal	av. 55.39x29.83	(potato dextrose agar) av. 33.85
McRae (134)	Cinchona	media	av. 52x33	av. 38
McRae (133)	cacao	media	av. 46x31	
McRae (133)	Borassus	media	av. 55-33	
Leonian and Geer (119)	"*P. Faberi*"	M/100 potassium nitrate sol.	mean 39.66x30.63	
Leonian and Geer (119)	"*P. palmivora*"	M/100 potassium nitrate sol.	mean 39.18x26.67	

P. arecae (all from *Areca catechu*)

Sundararaman and Ramakrishnan (208)	media	32-64x27-42	

Author	Substratum	Sporangia	Chlamydospores
Gadd (83)	media	48-70x30-48	24-48
Rosenbaum (183)	oat agar	mean 47.92x30.05	
Leonian and Geer (119)	M/100 potassium nitrate sol.	mean 34.52x24.67	
	P. meadii (all from *Hevea brasiliensis*)		
Dastur (53)	media	25-51x19-37	
Dastur (53)	Hevea fruits and stems	20.7-35.7x15-25.5 av. 28.5x20.4	17-34
McRae (132)	Hevea fruits	33-67x14-28 av. 48x21	
McRae (132)	water	17-44x15-29 av. 32x23	
McRae (132)	French bean agar	33-72x20-41 av. 48x30	16-47 av. 34
Sharples, Norris and others (194)	oat agar	mean 35.68x27.21	
McRae (133)	media	av. 27x20	

The recorded data indicate that *P. arecae* and *P. meadii* usually produce sporangia smaller than those of *P. palmivora*, and that they form chlamydospores with much less regularity. The widely variable character of the average dimensions of sporangia is noteworthy. For *P. palmivora* Peters (154) reported average dimensions as 38x26μ, while McRae (133) obtained averages of 55x33μ. For *P. meadii* McRae (132) (133) recorded averages of 48x30μ and 27x20μ.

The writer's data for the species is as follows:

Species	Sporangia	Chlamydospores
P. palmivora (typ.)	av. for 22 isolations 48.80x28.13	av. for 20 isolations 32-.37
P. palmivora (atyp.)	av. for 19 isolations 34.30x24.60	av. for 16 isolations 31-.24
P. meadii (No. 223)	av. 48.09x32.90	av. 29.4
P. meadii (No. 257)	av. 32.73x23.88	av. 24.7
P. meadii (No. 238)	av. 40.1x25.4	av. 27.8
P. arecae (No. 153)	av. 33.93x24.78	av. 25.74

P. meadii and *P. arecae* resemble the atypical isolations of *P. palmivora*. In Table 3 it may be noted that the average sizes of their sporangia are within the range of the species. In Table 8 the range of the average diameters of chlamydospores shows that *P. meadii* and *P. arecae* do not differ from numerous atypical isolations of *P. palmivora*.

In culture on corn meal *P. meadii* produced moderately profuse aerial mycelium and very sparse sporangia and chlamydospores. The same characteristic appeared in many of the atypical strains of *P. palmivora*. The writer obtained no oogonia in culture and has observed no character by which *P. meadii* may be distinguished from *P. palmivora*.

P. arecae resembled *P. meadii* and the atypical group of *P. palmivora* in growth characters, formation and size of asexual reproductive organs, and absence of oogonia. The 3 species cannot be separated by any marked differences in pathogenicity to the plants used for inoculation.

Examination of the data in Table 25 reveals no important differences in the temperature relations of the species. *P. arecae* did not grow at 32.5°C., but one isolation of *P. meadii* grew only slightly and some atypical strains of *P. palmivora* failed to grow at that temperature.

The single character of the development of oogonia in pure cultures of *P. meadii* and *P. arecae* is considered of minor importance on account of the rarity of its occurrence. In other characters the species are so similar that the writer believes *P. arecae* and *P. meadii* should be combined with *P. palmivora*.

Ashby (8) obtained oogonia in mixed cultures of *P. meadii* and *P. arecae*, while Gadd (83) failed to obtain them in mixed cultures of the Areca fungus with either *plus* or *minus* strains of *P. palmivora*, but the status of our knowledge of biochemical stimulation resulting in the appearance of oogonia, and of heterothallism in the genus does not justify the use of these characters in taxonomic studies. Furthermore, the use of reactions in mixed cultures would permit identifications only by those with access to living cultures of known *plus* or *minus*, male or female character.

8. *Phytophthora syringae* Kleb. Krankh. Flieders, Berlin:18. 1909.
Ovularia syringae Berk. Gard. Chron. II, 16:665. 1881.
Phlocophthora syringae Kleb. Centbl. Bakt. 15, II; 335. 1905.
Phytophthora hibernalis Carne Journ. Roy. Soc. W. Austral. 12:13. 1925.

"Mycel intercellular, vielfach verzweigt, einzellig, in älteren zuständen oft mit gewölbten, querwandähnlichen Bildungen, die der Protoplasmabewegung kein Hindernis bereiten, bei der Fruktifikation aber häufiger werden und dann der Abgrenzung leerer und plasmaerfüllter Hyphenstrecken dienen. Fädenförmige Haustorien in die Wirtzellen eindringend. Sporangien eiförmig, verkehrt eiförmig oder ellipsoidisch, 40-75: 30-42μ, nur im Wasser entstehend, einzeln endständig an dünnen Fäden oder zu mehreren (bis 7) in sympodial entwickelten Sporangienständen vereinigt, am Ende mit einem flachen Deckel, der bei der Entleerung verquillt und eine weite, abgestutzte Öffnung zurücklässt.

Sporangienwand nach der Entleerung gerunzelt. Inhalt schon vor dem Ausschlüpfen zerklüftet, in der Regel während des Ausschlüpfens, seltener gleich nach demselben in Schwärmsporen zerfallend. Diese eiförmig, 9-11: 8-9μ, etwas unsymmetrisch, seitlich mit 2 Geisseln, von denen die Kürzere (16-18μ) vorwärts, die längere (23-30μ) rückwärts gerichtet ist, lange schwärmend. Oogonien im Gewebe der Nährpflanze oder im Innern des festen Substrats entstehend, selten und ausnahmweise an Luftmycel, endständig oder interkalar, am Grunde nicht in einen Stiel verjüngt. Antheridien an Seitenhyphen, einzeln oder zu mehreren, an geschwollen, an unbestimmten Stellen mit breiter Fläche dem Oogonium sich anlegend. Oosporen einzeln im Oogonium entstehend, dasselbe fast ganz ausfüllend, meist rund, seltener oval, 18-36: 17-25μ. Membran dick, gelblich, glatt."

The above description by Klebahn (111) in 1909 followed earlier accounts of the fungus by Berkeley (17), who in 1881 described it as *Ovularia syringae*, and Smith (203), who in 1883 incompletely described "resting spores" in disease leaves. Wilson (236) in 1886 described the germination of sporangia by germ tubes and the development of zoospores. Klebahn (110) in 1905 made the species the type of a new genus Phloeophthora, founded on the absence of sporangia and the formation of oospores in the bark of a woody plant. Upon transferring it to Phytophthora in 1909 (111) he distinguished the species from *P. cactorum* by its non-papillate sporangia and their absence in cultures, and by the shape of the oogonia and the method of attachment of the antheridia. Himmelbaur (97) in 1911 distinguished *P. syringae* from *P. cactorum* by the lack of distinct papillae and the indefinite place of attachment of the antheridia to the oogonia. He reported smaller oospores in *P. syringae* and the production of oogonia in water cultures only.

P. hibernalis which the writer regards as identical with *P. syringae*, was described by Carne (37) in 1925. Petri (170) in 1927 noted the morphological similarity of the two species and considered it probable that they are the same.

The recorded data on the sporangia are as follows:

Author	*P. syringae* Substratum	Dimensions (micra)
Klebahn (111)	water	24-75x19-42 nonpapillate
Himmelbaur (97)	culture media	40-75x30-42 papillae lacking or indistinct.
Rosenbaum (183)	sterile beans or carrots	mean 39.86x25.33

Author	Substratum	Oogonia	Oospores
	P. syringae		
Lafferty and Pethybridge (113)	culture media		av. for 2 isolations 39x26.5 non-papillate
Peglion and Sacchetti (152)	lilac leaves		33-45x11-19
	P. hibernalis		
Carne (37)	lemon leaf tissue on potato dextrose agar.		17-56x10-21 av. 34.6x16.1
Moniz da Maia (183)	Citrus fruits		17.5-58x7.5-15
Bensaude (15)	Citrus leaves		25.2-54x12.6-27 av. 41x19.1 papillae flattened.
Bensaude (15)	potato agar		23.4-39.6x11-18 av. 30x14.4 papillae flattened

The writer has observed the flattened papillae in both species. They are indistinct but the sporangia are not non-papillate as in *P. cinnamomi* and similar species. Both produce sporangia very sparsely in culture on agar media and mycelium of *P. syringae* was placed in Petri's solution to obtain enough to permit measurement. The writer's measurements of sporangia are: *P. syringae* in Petri's solution, 21-33x15-27μ. Ave. 24.4x19.7μ. *P. hibernalis* on agar media, 28-41x15-33μ. Ave. 34.4 x17.9μ.

The small average size of the sporangia of *P. syringae* observed by the writer is widely different from the large sizes reported above by other writers, and it is apparent that little importance can be attached to so variable a character. The writer's data for *P. syringae* and *P. hibernalis*, obtained from very different substrata, are not comparable. The measurements for *P. hibernalis* are not very different from those previously recorded.

A similar comparison of the data for oogonia and oospores follows:

P. syringae

Author	Substratum	Oogonia (micra)	Oospores (micra)
Klebahn (110)	lilac tissues		18-28
Klebahn (111)	lilac tissues		18-36x17-25
Himmelbaur (97)	lilac tissues		30
Rosenbaum (183)	oat agar		mean 29.5
Lafferty and Pethybridge (113)	apple fruits	av. 26.4	av. 24.4
Lafferty and Pethybridge (113)	culture media	av. 28	av. 25.4

Author	Substratum	Oogonia	Oospores
Peglion and Sacchetti (152)	lilac tissues		24-35
	P. hibernalis		
Carne (37)	Citrus leaf tissue on potato dextrose agar.	22.4-56 av. 40.8	22-45.6 av. 35
Moniz da Maia (138)	culture media		22-42.5
Bensaude (15)	potato and oat agars.	19.8-44 av. 35.17	3-4 smaller than oogonia

These data show almost as wide variations as the data for sizes of sporangia. The writer's data, from a large number of oogonia and oospores produced under very similar conditions, follows: *P. syringae* on agar media; oogonia, ave. 28.4μ; oospores, ave. 25μ. *P. hibernalis* on agar media; oogonia, ave. 28.44μ; oospores, ave. 25.7μ.

The antheridia in the writer's cultures of *P. syringae* were paragynous. Lafferty and Pethybridge (113) reported the occasional occurrence of amphigynous antheridia in cultures of 2 isolations but paragynous ones were vastly more numerous. Klebahn (111) and Himmelbaur (97) observed the paragynous type.

In *P. hibernalis* the antheridia were paragynous in the writer's cultures on all media. Carne (37) and Bensaude (15) reported that amphigynous antheridia predominated with the occasional occurrence of paragynous ones. It seems probable that they considered antheridia in contact with the stalk of the oogonium amphigynous, while the writer regards as amphigynous only those antheridia whose intimate relation to the oogonial stalk indicates that they were penetrated by the developing oogonial incept. It is not uncommon to observe antheridia closely resembling the amphigynous type in cultures in which the paragynous type predominates; close examination usually shows that they have not been penetrated by the oogonium. However, in species in which the amphigynous type is characteristic, the presence of paragynous antheridia must be rare indeed. The writer has rarely found oogonia without antheridia in such species, but not with paragynous ones.

Both *P. hibernalis* and *P. syringae* caused a rot of apple fruits but did not attack potato tubers or eggplant fruits.

Both species grew most rapidly on corn meal agar at 15°C. and 20°C., made some growth at 5°C., and failed to grow at 25°C. They may be distinguished from the other species with paragynous antheridia by their low temperature requirements, especially their failure to grow at 25°C.

P. hibernalis is also very like *P. syringae* in growth characters and the writer believes that it should be included in *P. syringae*. The latter was long known only on Syringa, but Lafferty and Pethybridge (113) in 1922 isolated it from apple fruits, and various species of Citrus may now be included among its hosts.

9. *Phytophthora parasitica* Dast. Mem. Dept. Agr. India Bot. Ser. 5, 4: 177. 1913.
Phytophthora melongenae Saw. Noji Shikenjo Tokubetsu Hokoku, Taiwan 2:77. 1915.
Phytophthora allii Saw. Noji Shikenjo Tokubetsu Hokoku, Taiwan 2:59. 1915.
Phytophthora terrestris Sherb. Phytopath. 7:119. 1917.
Blepharospora terrestris (Sherb.) Peyr. Atti R. Accad. Lincei. Ser. 5, Rend. Cl. Sci., Fis., Mat. e Nat. 29, 1:194. 1920.
Phytophthora parasitica var. rhei Godf. Journ. Agr. Res. 23:1. 1923.
Phytophthora jatrophae Jensen (?)

"Maculis amphigenis, orbicularibus, centro arescentibus, dilute umbrinus, annulatis, solitariis vel confluentibus; mycelio intermatricali, ex hyphis inter- et intracellularibus, primo continuis, tandem septatis, 3-9μ crassis, constantibus; haustoriis sparsis, digitatis vel subglobosis, raro ramosis, sporangiophoris 100-300μ longis, sporangis terminalibus, interdum intercalaribus vel lateralibus, plerumque ovoideis, subinde globosis 25-50x20-40μ; zoosporis 8-12x5-8μ; sporis perdurantibus globosis, flavidis, 20-60μ, membrana crassa, levi; oogoniis et antheridiis in vitro cultis; oogoniis intercalaribus vel lateralibus, globosis, levibus vel rugosis, melleis, 18-25μ (23.8μ), pedicellis per antheridia penetrantibus; oosporis globosis, 15-20μ (18.6μ), membrana crassa, mellea, levi.

"Hab. in folii seminisque *Ricini communis* et *Sesami indici*. Indiae orient."

Ashby (8) in 1928 emended the species as follows: "*P. parasitica* Dast. is an omnivorous species of wide distribution ranging from the warm temperate to tropical latitudes with a high optimum temperature for growth (about 30°C. according to Fawcett and Godfrey). In culture on such standard media as bean and oat agars at 25°C., it develops an abundant white lanate and sparingly branched aerial mycelium, becoming matted and tough in tube culture, sterile at first but later forming sporangia scantily or in moderate numbers: the sporangia are typically prominently papillate and broadly ovate, exceeding in the mean 30μ in length and 25μ in breadth with a mean ratio of 1.4 or under; when young aerial growth is transferred to plain water, sporangia are formed abundantly in one or two days with a mean

ratio between 1.25 and 1.35. In older cultures, brown, thick-walled, mostly intercalary chlamydospores with a mean diameter of ± 30μ are usually formed in abundance. Sexual organs with amphigynous persistent antheridia are developed in pure cultures at moderate temperatures on standard media either readily and abundantly or late and scantily (the most favorable media are lima or French bean-meal agar and quaker oats agar). The oospores which mostly fill the oogonial cavity range from 12μ to over 35μ in diameter but the range in individual strains is much less; two groups can be distinguished:

1. *Microspora* having oospores of a mean diameter of under 20μ and a range of 12-24μ.
2. *Macrospora*, with oospores of a mean diamater of over 20μ and a range of 20–±35μ (a mean of 25–30μ in the known strains.)"

P. melongenae, according to Tanaka's (212) translation of Sawada's description, produced in culture on agar media sporangia averaging 42.4x33.9μ, chlamydospores 25-42μ in diameter, and oogonia varying from 18 to 24μ, with amphigynous antheridia and oospores 17-21μ in diameter. Ocfemia (145) in oatmeal agar cultures, obtained sporangia averaging 34.8x28.4μ chlamydospores averaging 29.1μ, oogonia 24-32μ, with amphigynous antheridia and oospores 16-24μ in diameter. The writer's No. 213 (*P. parasitica*) was labelled *P. melongenae* when received. It produced sporangia averaging 24.9x18.9μ, chlamydospores averaging 20.87μ, and oogonia and oospores with average diameters of 28.3μ and 24.4μ respectively. The antheridia were amphigynous. The writer's observations indicate smaller sporangia and chlamydospores and larger oospores than were reported by others, but the variations are of no importance in distinguishing *P. melongenae* from *P. parasitica*; the isolations of the latter are extremely variable, as may be noted in Tables 3, 5 and 11.

Godfrey (86), Curzi (49), Ashby (8), and Leonian and Geer (119) noted the marked similarities between *P. melongenae* and *P. parasitica*, and Ashby (8) and Leonian and Geer (119) combined the species. The writer's observations confirm the synonymy of the names. No characteristic was found by which they may be distinguished.

P. allii is not in the writer's collection. The only record of it, so far as the writer knows, is Sawada's description, translated by Tanaka (212). He reported sporangia averaging 49.4x36.5μ and oogonia and oospores on agar media with average diameters of 20.7μ and 16.9μ respectively. The antheridia were amphigynous. Ashby (8) regarded *P. allii* as identical with his section *Microspora* of *P. parasitica*, and Leonian and Geer (119) noted that it could possibly be included in their *P. omnivora*. The small

size of the oospores and the amphigynous antheridia are good evidence that it should be considered *P. parasitica*. The writer has not found oospores as small as those reported for *P. allii* outside *P. parasitica*.

P. terrestris, according to Sherbakoff (196) produces reproductive organs of the following average sizes: sporangia, 42.5x30.5μ; chlamydospores, 34μ; oogonia, 22μ, and oospores, 20μ. The antheridia are amphigynous. He distinguished it from *P. erythroseptica*, *P. citrophthora* and *P. cactorum* partially by its tufted, irregular growth on corn meal agar, a characteristic of many isolations of *P. parasitica*, a species he did not consider in his comparisons. The writer's Nos. 164, 167, and 171, received as *P. terrestris*, and No. 159, labelled *P. terrestris var. rhei*, proved indistinguishable from *P. parasitica*.

Godfrey (86) and Curzi (49) regarded *P. terrestris* as very similar to *P. parasitica*. Bruner (26) found them identical morphologically but retained *P. terrestris* on the basis of differences in pathogenicity. Butler (33), Bewley (19), Ashby (8) and Leonian and Geer (119) considered them identical.

Blepharospora terrestris was considered the correct classification of *P. terrestris* by Peyronel (171). The transfer appears unwarranted, and the genus Blepharospora is probably not distinct from Phytophthora.

P. parasitica var. rhei was established by Godfrey (86) for the following reasons: the rhubarb fungus proved slightly less pathogenic to *Ricinus communis* than *P. parasitica*; it infected tomato fruits while Dastur (52) reported negative results with *P. parasitica*; it produced oospores in corn meal agar while Dastur (52) failed to obtain them; the oospores averaged about 25μ in diameter but Dastur (52) reported them 18.6μ for *P. parasitica*. None of the criteria used to distinguish the variety are valid and it may better be considered simply *P. parasitica* as suggested by Ashby (8). Leonian and Geer (119) also regarded it as identical with this species. The writer's examination of 4 cultures from rhubarb revealed no characters by which they may be considered different from *P. parasitica*.

P. jatrophae Jens. probably has not been described. Pethybridge (157) and Wilson (238) also failed to find a description. Rutgers (185) in 1917 distinguished it from other species by its small, usually asymmetrical sporangia and the production of oogonia with amphigynous antheridia. Rosenbaum (183) reported the mean size of the sporangia as 49.65x37.55μ and of the chlamydospores as 32.89μ. He obtained no oospores on oat agar. Ashby, in a letter wrote, ". . . . .the studies of Rosenbaum and Rutgers indicate that it (*P. jatrophae*) might serve as a name for a good many strains from tobacco, etc., which seem to come between *P. palmivora* and *P. parasitica*." The writer has not seen the spe-

cies, but the recorded evidence indicates that *P. jatrophae* may be considered synonymous with *P. parasitica.*

Leonian (116) included *P. parasitica* and other species in *P. omnivora,* a classification which was opposed by Ashby (8).

The species is common, and considerable data regarding various isolations have been recorded, some of which, for the asexual reproductive organs, are as follows:

Author	Substratum	Sporangia (micra)	Chlamydospores (micra)
Dastur (52)	media	11-60x10-45 usually 23-50x20-40	20-60
Rosenbaum (183)	lima bean agar	mean 43.64x23.39	mean 31.15
Ashby (5)	lima bean agar	23-58x19-42 mean 37.4x28.3	25-57 mean 36.4
Kendrick (109)	liquid cultures	53.2-55.8x45.9-50 av. 54.9x47.6	
Kendrick (109)	agar media	33-92.5x29.5-33 av. 41x31	av. 24.7
Tisdale and Kelley (225)	oat agar	15.7-52.5x14.7-42 av. 31.2x25.9	10.5-45.5 av. 26.9
Nolla (144)	oatmeal agar	25.4-69x17.2-46.6 mean 47.4x35.8	mean 29.3
Leonian and Geer (119)	M/100 potassium nitrate sol.	mean 40x31.9	

The above data illustrate the variability within the species. The writer's measurements in Table 3 show that the average lengths of the sporangia of different isolations vary from 27.05μ to 59.68μ and the diameters from 17.70μ to 38.41μ. The writer believes that the size of the sporangia and the ratio of length to diameter are of less importance in the delineation of the species than Ashby (8) suggested in his emendation previously quoted. In the majority of isolations the sporangia fall away without a persistent pedicel but this, again, is a variable character, which, although of some value in distinguishing the species, cannot be relied upon very strongly.

All the writer's isolations produced chlamydospores more or less profusely, at least in the old cultures, but there is little uniformity in size; for example, No. 205 produced chlamydospores with an average diameter of 17.68μ while those of No. 185 averaged 29.60μ.

The occurrence of oogonia and oospores in culture is uncertain. Isolations seldom produce them very promptly; they may appear only after several months or, frequently, not at all. Considerable variation in the size of oogonia and oospores is apparent in different isolations

and even in the same one cultivated on different substrata. Some of the recorded data are as follows:

Author	Substratum	Oogonia (micra)	Oospores (micra)
Dastur (52)	French bean agar	15-27 av. 23.8	av. 18.6
Dastur (52)	oat agar	25-35	13-24 av. 18.6
Ashby (5)	lima bean agar	av. for 3 strains 24.1	av. for 3 strains 18
Kendrick (109)	agar media		17.5-26 av. 21
Lester-Smith (120)	lima bean agar		13-22.5 av. about 18.3

Ashby (8) reported a number of isolations with oospores with a mean diameter of 25-30μ which he placed in his section *Macrospora*. According to his scheme most of the isolations tabulated above would fall into the section *Microspora*.

The records indicate that the antheridia are amphigynous in all isolations. The only divergent record is by Cooper (47) who was unable to find any amphigynous ones.

In the writer's study of many isolations of *P. parasitica*, more than half of which produced oogonia, the antheridia were always amphigynous (Figs. 8 and 9). The size of oospores was a variable character, some isolations agreeing with Ashby's (8) section *Microspora*, others with *Macrospora*, while others appeared intermediate in character and could not be referred to either section with certainty. The writer prefers to consider all isolations as simply *P. parasitica*.

A consideration of Table 24 shows that all isolations of *P. parasitica* developed on corn meal agar at 35°C., while none of *P. palmivora* did. This distinction seems to provide a fairly quick and certain method for separating *P. parasitica* and some of the atypical isolations of *P. palmivora* which resemble *P. parasitica* in growth on media and exhibit delayed formation of reproductive organs. The other species that develop at 35°C. are *P. hydrophila*, *P. capsici*, *P. nicotianae*, and *P. drechsleri*. *P. hydrophila* and *P. capsici* will be shown to be synonymous and distinguishable from *P. parasitica* by the absence of chlamydospores in culture and by distinct differences in pathogenicity. *P. nicotianae* is morphologically identical with *P. parasitica* but will be considered a variety on pathogenicity characters. *P. drechsleri* differs in sporangium characters.

On culture media *P. parasitica* usually produces aerial mycelium in profusion. The growth in petri plates is seldom radiate and appressed

as is common in *P. palmivora*, *P. citrophthora* and some other species, but tufted and irregular with more or less aerial mycelium (Fig. 1). Some isolations, however, produce smoothly circular growth of a homogeneous character, and the same single strain culture may produce various types of growth on different media and on the same substratum when incubated at different temperatures.

The writer finds that *P. parasitica* may be distinguished by its growth on media, papillate sporangia, abundant chlamydospores in culture, amphigynous antheridia and growth on corn meal agar at 35°C.

10. *Phytophthora parasitica var. nicotianae* n. var.
Phytophthora nicotianae Breda de Haan Med. Lands Planten. Java 15, 107 pp. 1896.
Phytophthora tabaci Saw. Rept. Dept. Agr. Res. Inst. Formosa 27, 73 pp. 1927.

Differs from *P. parasitica* Dast. (emend. Ashby) only in attacking the roots, stems and leaves of tobacco (*Nicotiana tabacum*) at any stage of growth, causing the widely distributed and important disease known as black shank.

P. nicotianae was originally described by Breda de Haan (24) in 1896. He did not grow it in pure culture, and his mention of oogonia 19μ in diameter and paragynous antheridia (23) has been confusing to later investigators. Sawada (189) separated *P. tabaci* from *P. nicotianae* on account of the amphigynous antheridia in cultures of the former. Breda de Haan's (24) description of the fungus was incomplete, but subsequent writers have referred Phytophthoras occurring on tobacco to *P. nicotianae*, sometimes without any certainty that they agreed with the fungus described by Breda de Haan further than in occurring on tobacco.

Breda de Haan (23) in 1893 considered the tobacco fungus closely related to *P. omnivora*, but in 1896 (24) he separated it as *P. nicotianae* on differences in sporangium size, but wrote no formal description of the species. Jensen (101) in 1906 considered it very similar to or possibly identical with *P. infestans*. Lodewijks (123) in 1909 regarded the Javan tobacco fungus as different from *P. nicotianae* as described by Breda de Haan (24) on account of its larger sporangia and its ability to grow in culture. Rutgers (185) in 1917 distinguished *P. nicotianae* by its small sporangia with very large papillae. Lafferty and Pethybridge (113) in 1922 stated that *P. jatrophae* may be identical with *P. nicotianae*. Tisdale (221) in 1922 noted the morphological similarity in culture between *P. nicotianae* and *P. parasitica*. Leonian (116) reported the two species very similar physiologically as well as morphologically. Lester-Smith (120) observed similarities in sporangium size between *P. parasitica* and *P. nicotianae*, but considered the latter possibly a

strain or form of *P. palmivora* on account of its behaviour in mixed cultures with isolations of that species. Ashby (8) in 1928 eliminated *P. nicotianae* and included the black shank organism in *P. parasitica* as a member of his section *Macrospora*.

It seems worthwhile to list some of the recorded data as follows:

Author	Substratum	Sporangia (micra)	Chlamydospores (micra)
Breda de Haan (24)	tobacco plants	av. 36x25	
Lodewijks (123)	media	av. 48.6x37	
Rosenbaum (183)	lima bean agar	mean 37.6x30	mean 28.8
Tisdale and Kelley (225)	oat agar	av. for 3 strains 36.4x26.8	av. for 2 strains 23.8
Lester-Smith (120)	tobacco leaves in water	av. 45.7x32.5	(lima bean agar) 21.6-57.6 av. 34
Nolla (144)	oatmeal agar	av. for 4 strains 46.6x37.8	av. for 4 strains 35.3

The writer has examined cultures from Florida, Porto Rico and Sumatra and found the following average sizes for the asexual reproductive bodies produced on agar media.

No.	Source	Sporangia (micra)	Chlamydospores (micra)
216	Florida	35.1x25.2	28.6
232	Porto Rico	41.2x31.7	23.9
247	Sumatra	40.2x28.7	21.4

As in *P. parasitica* the sporangia and chlamydospores vary considerably in size, and in appearance are identical with some isolations of *P. parasitica*.

The writer found a few oogonia in old cultures only. Jensen (103)' Tisdale and Kelley (225), Rosenbaum (183) and Lester-Smith (120) failed to obtain them. Nolla (144), reported oogonia in soil, but reported no measurements; his drawings indicate that they were probably of a *Pythium sp.* rather than *P. nicotianae*. The following data will serve for comparison with the writer's observations:

Author	Substratum	Oogonia (micra)	Oospores (micra)
Breda de Haan (23)	tobacco stems	19	
Lodewijks (123)	media	21-28	
Ashby (8)	oatmeal agar	av. 30	av. for 2 strains 24.3

The writer's average measurements, based on a small number of observations on account of the limited production of sexual organs, follow:

No.	Source	Oogonia (micra)	Oospores (micra)
216	Florida	29.1	25.2
232	Porto Rico	28.7	24.9
247	Sumatra	25.6	21.4

The writer's data agree fairly closely with Ashby's (8); Breda de Haan's (23) report of 19μ for the diameter of the oogonia, as has been mentioned, must be considered doubtful.

In growth characters on media and in development at various temperatures the black shank fungus appears identical with *P. parasitica*. In pathogenicity to hosts other than tobacco *P. nicotianae* also resembles *P. parasitica*. On tobacco plants with well developed stems all isolations of *P. parasitica* and other species proved nonpathogenic, while *P. nicotianae* caused typical symptoms of black shank and killed the plants. It has been observed that *P. parasitica* may attack small seedlings and cause a stem rot or damping off, but, as previously mentioned in the discussion of inoculations of tobacco, the writer and others failed to infect older plants with *P. parasitica*. This distinct difference in pathogenicity may be considered due to the presence of biological strains in *P. parasitica*, but the writer has not found much evidence of the existence of such sharply defined specialization. Less strikingly specialized strains certainly occur, but one could hardly use their pathogenic reactions to differentiate them, with certainty, from other strains. The black shank fungus, however, may be definitely distinguished from all others by its ability to cause black shank.

Ashby (8) included *P. nicotianae* in *P. parasitica*. The writer believes that a distinguishing name for the fungus responsible for black shank will prove convenient, and on the basis of pathogenicity proposes *P. parasitica var. nicotianae*.

P. tabaci is known only from Sawada's (189) description, a translation of which was sent by S. F. Ashby. Sawada (189) reported that it causes a disease of the stems of *Nicotiana tabacum* in Formosa. The lesions are at first water soaked, then olivaceous and finally brown, the stem becoming dark internally. His description of the disease is incomplete, but it indicates that he referred to black shank. He reported sporangia on bean agar 43-74x33-64μ; chlamydospores on bean agar averaging 36.6μ, and scanty production of sexual organs on bean agar. The oogonia were 26-30μ (average 28.1μ), the oospores 21-24μ (average 23μ) in diameter. The antheridia were amphigynous and he stated that it differed from *P. nicotianae* in this respect; he apparently was confused by Breda de Haan's (23) early reports of paragynous antheridia.

A culture received by the writer labelled *P. tabaci* turned out to be a Pythium, but Sawada's (189) description proves that he was dealing with a Phytophthora and, the writer believes, one identical with *P. nicotianae*. Ashby in a letter stated, "I should probably have put *P. tabaci* in my section *Macrospora* of *P. parasitica*. The writer includes *P. tabaci* in *P. parasitica var. nicotianae*.

11. *Phytophthora erythroseptica* Pethyb. Sci. Proc. Roy. Dublin Soc. 13:529. 1913.
Phytophthora erythroseptica var. atropae Alcock Pharmaceut. Journ. 116:232. 1926.

"Mycelio ramo quoad partes recentiores non septato quoad vetustiores multiseptato vacuotoque conidiis inversipyriformibus aut propemodum ovoideis sympodialiter genitis 32x20μ. Antheridiis terminalibus aut lateralibus aut intercalariis rotundis aut ovoideis penetratis ad vel iuxta bases suas oogoniis incipientibus quae deinde ex partibus summis emergunt. Oogoniis pyriformibus super hyphas quae origine distant ab illis hyphae quae illa antheridia gignunt partes inferiores intra antheridia habentibus oosporis sphaericis crasso subfusculo episporio praeditis 29-30μ. Invenitur inter tuberis cellulas *Solani tuberosi* quas enecat. Hae cellulae tubere secto ad aerem nudatae colorem primo rubescentem postae prope nigrescentem prae se ferunt.

"Hab. in Hibernia hesperia et boreali."

Pethybridge (155) in 1912 regarded the potato pink rot fungus as probably *P. omnivora*, but described it as a new species in 1913 (156) largely on the results of studies on the development of the sexual organs as recorded in the above description. Rosenbaum (181) in 1914 considered *P. arecae* and *P. erythroseptica* very similar or identical when both caused a pink rot of potato tubers. Leonian (116) in 1925 considered *P. erythroseptica* and *P. mexicana* very similar, and Leonian and Geer (119) in 1929 favored combining the species; they reported the chief difference between them to be the shape of the papillae and regarded this as a doubtful and variable distinction.

Mrs. Alcock (2) in 1926 suggested the name *P. erythroseptica var. atropae* for a fungus on *Atropa belladonna* which she considered distinct on account of its failure to attack potatoes in the field, its occurrence as a stem parasite where it produced masses of oospores while *P. erythroseptica* rarely produced them in potato tubers, the larger sporangia, and the absence of pink color in potato tubers rotted by it. The reasons for separating the Atropa strain are not very convincing, and, pending further evidence, the writer prefers to include it in *P. erythroseptica*.

Pethybridge (156) failed to obtain sporangia on solid media. In liquid cultures they were non-papillate, ovate to obpyriform, averaging

32x20μ. Rosenbaum (183) reported their formation on inoculated sterilized flies, mean 44.8x27.6μ. Westerdijk and van Luijk (232) reported sporangia on bits of an agar culture of an Atropa strain placed in water, averaging 44x26.5μ. Their drawings are of non-papillate sporangia.

The writer, using a single isolation, obtained slight aerial development on steamed corn meal, and fairly profuse growth on the agar media. No sporangia were produced and chlamydospore-like vesicles were found rarely in only one culture. In M/100 potassium nitrate solution *P. erythroseptica* produced an occasional non-papillate, obpyriform sporangium.

Oogonia and oospores were reported by Pethybridge (156) with average diameters of about 36μ and 29-30μ; by Rosenbaum (183), on agar, oospores averaging 35.78μ; by Westerdijk and van Luijk (232), on corn meal, oospores of a potato strain averaging 32.61μ and of an Atropa strain, 32.79μ in diameter. The writer's data in Table II on sexual organs from old oatmeal agar cultures show oogonia averaging 36.3μ and oospores averaging 31.4μ.

The antheridia are amphigynous as reported by others, except Cooper (47) who failed to observe them.

P. erythroseptica grew only slightly on corn meal agar at 15°C., profusely at 27.5° and did not develop at 30°C. The rather narrow temperature range may serve as an aid in distinguishing it from other species which produce non-papillate sporangia. Other characteristics of importance are the large size of the oospores and the absence of chlamydospores. The writer does not agree with Leonian and Geer (119) that *P. mexicana* should be combined with *P. erythroseptica*. The non-papillate sporangia of the latter are considered a distinguishing character. *P. mexicana*, while a very scanty producer, has never produced sporangia in the writer's cultures resembling those of *P. erythroseptica*. The two species are also different in their temperature relations and in the size of the oospores.

12. *Phytophthora cambivora* (Petri) Buis. Root Rots caused by Phycomycetes. Typ. Hollandia-Drukkerij. Baarn. 1927.
Blepharospora cambivora Petri Ann. R. Ist. Super. Forestale Naz. Firenze, 3:151. 1918.

"Zoosporangi limoniformi, terminali su rami semplici, misuranti 40-54x60-75μ. Micelio abbondante nelle e settato, nel tessuto dell' ospite quasi sempre unicellulare, formante austori globosi o filamentosi. Zoospore ovoidali di 12-15μ, con un' estremita assotigliata, munite di due ciglia vibratili. Oospore sferoidali, alla maturita leggermente colorite in fuligeneo, 20-27μ di diametro, anteridi originati da ife diverse da quelle oogonifere."

Prior to his publication of this formal description Petri (164) in 1917 referred to the fungus as *B. cambivora*. In 1922 (166) he separated it from *P. citrophthora*, *P. cactorum* and *P. crythroseptica* by growth characters in culture as well as by its production of reproductive organs in inorganic nutrient solutions only. The latter character he regarded as the principal difference between Blepharospora and Phytophthora. In 1924 Petri (168) observed oogonia and paragynous antheridia in the tissues of chestnut seedlings and considered his fungus closely related to the species of Phytophthora with similar antheridia; he retained Blepharospora on account of the biological peculiarities and the long, simple sporangiophores terminating in a single sporangium. Later (169) he reported oogonia with amphigynous antheridia in cultures on carrot agar. Dufrenoy (64) in 1926 noted that *B. cambivora* is very similar, morphologically, to Phytophthora, but, in the same year, as a result of cytological studies (65) he considered it closely related to Saprolegnia.

Buisman (31) in 1927 transferred the fungus to Phytophthora as *P. cambivora*, and regarded it as near *P. cryptogea*, *P. cinnamomi*, and *P. richardiae*, all of which produce non-papillate sporangia rarely on solid media, but more frequently in liquid cultures and exhibit renewed growth of the sporangiophores through the empty sporangia. Leonian and Geer (119) in 1929 also considered the fungus a Phytophthora and observed the blunt, non-papillate sporangia.

Petri (165) reported sporangia 60-75x40-54μ in his inorganic nutrient solution; oospores 20-27μ in diameter occurred in diseased tissues. In 1924 (167) he observed the development of new sporangia within the empty walls of old ones and considered this a distinguishing character. In 1925 Petri (169) obtained oogonia 57-62μ in diameter with amphigynous antheridia. No oospores were observed. He also noted the development of spheroidal to irregular bodies, frequently in clusters and groups, at the tips of hyphae; when transplanted they produced new hyphae. Leonian and Geer (119) reported non-papillate sporangia of a mean size of 37.44x23.71μ in M/100 potassium nitrate solution. Ashby (11) found oogonia with amphigynous antheridia occurring very rarely in a corn meal agar culture 9 months old. Three oogonia averaged 47μ and the oospores 38.8μ.

The writer's cultures of *P. cambivora* (Nos. 198 and 208) failed to produce reproductive bodies, except in old cultures of No. 208, which produced swollen, clustered vesicles or chlamydospores as observed by Petri (169). The bodies are similar to those developed abundantly by *P. cinnamomi*. No. 198 produced non-papillate sporangia 32-65x23-41μ (average 47.6x31.1μ) in Petri's solution and renewed growth of the sporangiophores through the empty sporangia was noted. The writer did not obtain oogonia. The optimum temperature is between 25° and

30°C., and no growth occurred at 35°C. *P. cambivora* attacked wounded apple fruits weakly and failed to infect potato tubers and all other hosts inoculated.

The species may be distinguished from similar ones by its practically sterile growth of mycelium on ordinary media, its temperature relations and pathogenic characters. *P. cinnamomi* produces vesicles abundantly. *P. richardiae* is non-pathogenic to apple fruits, and grows at a decidedly lower temperature range. *P. cryptogea* grows at lower temperatures and is pathogenic to potato tubers. *P. cambivora* is certainly a Phytophthora and seems to be a valid species distinct from all others.

13. *Phytophthora cryptogea* Pethyb. and Laff. Sci. Proc. Roy. Dublin Soc. 15:487. 1919.

"Mycelio ramoso quoad partes recentiores eseptato vetustiores septato; conidiis plerumque inversipyriformibus 24-50x17-30μ, apicibus obtusis non-papillatis sympodialiter genitis; zoosporis 2-ciliatis 10-15μ diam.; oogoniis hyalinis flavescentibus pyriformibus 30μ diam.; antheridiis amphyigynis hyalinis; oosporis sphaericis flavescentibus crasse episporio praeditis 25μ diam.

"Hab. in radicis caulibusque vivis *Lycopersici esculenti et Petuniae sp.* in Hibernia."

Robinson (178) in 1915 isolated a fungus resembling *P. cryptogea* from Aster sp. Pethybridge and Lafferty (162) distinguished it by its non-papillate sporangia, scanty development of reproductive organs in culture, the size and color of the sexual organs and its host relationships. Leonian and Geer (119) retained the species on physiological characters. Ashby (10) regarded *P. richardiae* as very similar to *P. cryptogea* and proposed it as a variety, *P. cryptogea var. richardiae.*

Pethybridge and Lafferty (162) recorded non-papillate sporangia on tomato stems and a few in cultures, 24-50x17-30μ (average 40x27μ), and oogonia averaging 30μ in old oatmeal agar cultures, with oospores 25μ in diameter. The growth of the sporangiophores through empty sporangia and development of new sporangia within or beyond the old were observed. Ashby (10) reported on 3 strains which produced non-papillate sporangia and developed oogonia in pure culture only after some time. In mixed culture with *P. cinnamomi* oogonia were abundant after 9-10 days; their distribution in the growth zone of *P. cryptogea* indicated their production by this species; the oogonia were 24-34μ (average 28.3μ) and the oospores, 19-29μ (average 23.7μ). Sporangia produced on a flower stalk (*Tulipa sp.*) in water had a mean size of 43.9x29.8μ and those of a pure culture in water 32.3x22.8μ. All observers reported amphigynous antheridia.

Mrs. Alcock (3) reported a Phytophthora in strawberry roots which she considered possibly a strain of *P. cryptogea*. It was not isolated. From her description the writer is inclined to regard it as more probably *P. erythroseptica* on account of the very large oospores which agree more closely with that species.

The writer's culture of *P. cryptogea* grew on all media used. No sporangia developed on the solid substrata and swollen vesicles in the hyphae resembling those sometimes formed by *P. cambivora* and very commonly by *P. cinnamomi*, were found in old oatmeal agar cultures (Fig. 11). Oogonia were present in oatmeal agar cultures after exposure to winter temperatures at Columbia, Mo. The oogonia averaged 25.8μ and the oospores 22.8μ. The antheridia were amphigynous (Fig. 7). In Petri's mineral solution *P. cryptogea* produced non-papillate sporangia 25-49x16-29μ (average 36.7x21.9μ), and exhibited the renewed growth of sporangiophores through the bases of evacuated ones as reported by other observers.

P. cryptogea is a member of the group containing *P. cambivora*, *P. cinnamomi*, *P. erythroseptica*, *P. richardiae* and *P. drechsleri*. It grew more rapidly at 5°C. than any isolation studied, made its optimum growth at 25°C. and failed to grow at 32.5°C. *P. cryptogea* differs from *P. cambivora* in temperature relations, in pathogenicity, and in the size of the sexual organs; from *P. cinnamomi* in the rare development of vesicles in cultures, in growth characters, and in pathogenicity; from *P. erythroseptica* in the size of the oospores and in temperature relations; from *P. richardiae* in pathogenicity and in temperature relations; from *P. drechsleri* in temperature relations.

14. *Phytophthora capsici* Leon. Phytopath. 12:401. 1922.
Phytophthora hydrophila Curzi Riv. Pat. Veg. 17:1. 1927.

"Sporangiophores branched; sporangia generally ovoid, varying in culture to elongated ellipsoid, subsphaeroid, irregularly elongate with intermediate forms; papilla very prominent, either single and apical, or sometimes up to three and variously disposed; germination normally by zoospores, under special conditions by germ tubes; size of sporangia extremely variable, 35-85μ or even 105x21-56μ, averaging 60x36μ; oospores formed on submerged mycelium, abundant on oatmeal and corn meal agars, slightly wrinkled, brown, semi-transparent, 25-35μ; antheridia basal; mycelium often gnarled, becoming densely tuberous under certain cultural conditions; the tuberous outgrowths sphaerical or ovoid, minute, 5-8μ, of the same shape as sporangia, richer in protoplasm and darker in color than the mycelium, often very numerous, giving rise to large, grape-like clusters, germinating by germ tubes; no chlamydospores observed.

"Parasitic on stems and fruit of *Capsicum annuum*. State College N. Mex."

Leonian (115) separated *P. capsici* as a new species on account of the development of gnarled, tuberous hyphae, sporangia larger than in *P. parasitica*, more frequent oospore development than in *P. infestans*, and more prominent papillae than in *P. erythroseptica*. In 1925 (116), on the basis of their behavior on various culture media, he regarded *P. citrophthora* and *P. capsici* as very similar; Leonian and Geer (119) in 1929 favored combining *P. capsici* with *P. citrophthora*, which, according to their scheme of classification, is included in *P. omnivora*.

Leonian (115) reported papillate sporangia 35-105x21-56μ (average 60x36μ), and oospores in oatmeal and corn meal agar cultures 25-35μ in diameter. No chlamydospores were observed.

P. hydrophila was isolated from pepper in Italy by Curzi (49) who reported the sporangia on solid media mostly 35-60x22-35μ, and oogonia in bean dextrose agar 28-35μ. The antheridia were amphigynous. No chlamydospores were found. Curzi (49) distinguished *P. hydrophila* from *P. parasitica* by the absence of long aerial hyphae, the absence of chlamydospores and differences in the size of the sexual spores. He regarded it as different from *P. capsici* in producing no oospores in oatmeal agar, in producing less aerial mycelium in cultures, in its more virulent pathogenicity to pepper, and in having slightly smaller hyphae less variable in diameter.

The writer isolated a Phytophthora (No. 253) from young pepper plants attacked near the tips during wet weather in Porto Rico. The fungus invaded the stems and leaves and killed the plants. Healthy plants placed in infected soil under drier conditions were attacked near the base of the stems. The fungus (No. 253) is here included as *P. capsici*. The writer's observations on Nos. 147 and 253 (*P. capsici*), and No. 241 (*P. hydrophila*) follow:

No.	Sporangia	Oogonia (micra)	Oospores (micra)
147	16-69x12-31 av. 30x20.8	23.4-33.4 av. 28.7	20.9-29.2 av. 24.9
253	24-59x18-41 av. 37.9x27	17.5-34.2 av. 28.2	15-30.1 av. 24.8
241	27-58x23-48 av. 46.9x35.9	25.1-32.6 av. 29.1	19.2-30.1 av. 24.4

All 3 produced sexual organs in old cultures only; in average size they agree very closely. Sporangia were produced fairly profusely on most media, and the writer's average dimensions show wide variations between the strains. Those variations are probably of no significance

when one considers that Leonian (115) reported sporangia 60x36μ for *P. capsici* while the writer, using a strain long in culture, obtained averages of 30x20.8μ. True chlamydospores were not produced; No. 147 formed a few swollen hyphal structures (Fig. 12) resembling the bodies described by Leonian (115) in potato dextrose agar, and they also occurred rarely in cultures of No. 253 on lima bean agar.

The growth characters on different media showed no significant differences between the isolations. No. 147 grew a little more slowly than Nos. 241 and 253. The temperature relations (Table 24) show the weak growth of No. 147 in comparison with the other isolations. It grew only slightly at 32.5°C., while Nos. 253 and 241 grew at 35°C. No. 147 seems to resemble in this respect, an isolation of *P. palmivora*, No. 272, which grew more slowly on corn meal agar than most of the isolations of the same species, and only slightly at 30°C., while most of the others grew luxuriantly at 32.5°C. In the case of No. 272 the weak growth was a character of the isolation and not an effect of long cultivation on media.

P. capsici may be regarded as having temperature relations very similar to *P. parasitica*, for the behavior of Nos. 241 and 253, more recently isolated, may be regarded as more typical than that of No. 147. An examination of fresh isolations of *P. capsici* from New Mexico is desirable.

A comparison of the results of inoculations with the isolations reveals very similar pathogenic characters. All were rather virulent on most hosts, attacking apple fruits, potato tubers, tomato fruits and seedlings, eggplant fruits and seedlings, and Ricinus, papaw and cacao seedlings. No. 147 was slightly less virulent than No. 253 to Ricinus and papaw seedlings and slightly more virulent to eggplant seedlings. No. 241 differed from Nos. 147 and 253 only in its pathogenicity to wounded cotton bolls. As previously mentioned all attacked inoculated pepper stems, while all other isolations, including 2 of *P. parasitica* isolated from pepper fruits, failed to infect them. The evidence indicates that all 3 must be regarded as *P. capsici*.

Leonian and Geer (119) proposed the combination of *P. capsici* and *P. citrophthora*. The writer does not favor this for the following reasons: all strains of *P. citrophthora* infected citrus shoots and were non-pathogenic to pepper stems, while *P. capsici* infected pepper but not citrus; *P. capsici* failed to produce chlamydospores while *P. citrophthora* produced them regularly in old cultures; *P. capsici* has a higher temperature range and optimum than *P. citrophthora*.

15. *Phytophthora cinnamomi* Rands Dept. Landb. Nijv. Handel. Meded. 54, 53 pp. 1922.

"Mycelium penetrating bark and outermost layers of wood; irregular, sparingly branched, inter- and intracellular, bearing occasionally chlamydospores in the tissues; aerial hyphae on oat agar hyaline, slender, 5-7μ in diameter, with age becoming thick walled and septate, haustoria not observed.

"Chlamydospores thin walled, globose to pyriform 28-60μ (mostly 31-50μ) in diameter, average 41μ; terminal on short lateral branches; abundant in artificial cultures, frequently occurring in grape-like bunches or clusters of 3-10 spores; germinating by 3-11 germ tubes.

"Conidiophores undifferentiated, simple or sympodially branched.

"Conidia (sporangia) not produced in nature nor in ordinary artificial cultures, but abundantly produced on mycelium transferred from nutrient solution to water; borne terminally and varying in shape from, ovoid to ellipsoid or elongate, hyaline, thin walled, with broad, flat inconspicuous papilla on end opposite point of attachment; size 25-100x18-43μ, mostly 38-84x27-39μ, average 57$\times$33μ; secondary conidia produced on branches of conidiophore in successive sympodial fashion, but frequently also by successive proliferation through the empty ones; spore case partially collapsing after discharge, germinating in water generally by liberation of zoospores but occasionally by a tube developing hyphae or secondary conidia, conidial discharge in weak or contaminated cultures often abnormal, the zoospores failing to separate and the extruding mass disintegrating.

"Zoospores 8-40 from one conidium, more or less bean or kidney shaped with two flagella of unequal length attached to concave side, (as seen after treatment with drop of JJK solution); while swimming $\pm$ 11x18μ, and after coming to rest 10-11μ in diameter; germinating after about an hour by a tube.

"Oospores not observed.

"Causing stripe canker of the bark of *Cinnamomum burmanni* Bl. (Malay *kulit manis*) in West Coast Highlands of Sumatra.

Gadd (83) in 1927 suggested that *P. cinnamomi* may belong to the group of tropical strains similar to *P. faberi*. Ashby (8) considered the large, obpyriform, non-papillate sporangia a distinguishing character and (10) considered it near *P. cambivora* since both produced vesicles on solid media.

Ashby (8) obtained oogonia with amphigynous antheridia and oospores over 30μ in diameter in mixed cultures of *P. cinnamomi* and a strain of *P. parasitica* which had small oospores in pure culture; he regarded the large ones as those of *P. cinnamomi*. He later (11) found

broadly clavate oogonia with the wide funnel-shaped base within the antheridium, in an old pure culture on corn meal agar. The oogonia averaged 32μ, and the oospores 27.2μ in diameter. The writer has mentioned the development of oogonia with amphigynous antheridia in one strain when mycelium was placed in M/100 potassium nitrate solution. The oogonia averaged 28.1μ and the oospores 25.7μ.

The abundant production of the swollen vesicles, superficially resembling chlamydospores, is a character peculiar to *P. cinnamomi* (Fig. 10). Their development in other species has been very limited in the writer's cultures. Measurements in Table 8 indicate that in average size they do not differ from the chlamydospores produced by some other species. The sporangia were not observed on the solid media used. In Petri's solution they were non-papillate. A Sumatra isolation (No. 174) produced sporangia with an average size of 43.6x25.9μ, and a Porto Rico isolation (No. 242), 46.1x31.3μ. These sizes are very similar to the average for *P. cambivora*, and are further evidence of the close relationships of the two species suggested by Ashby (8). However, the smaller oospores of *P. cinnamomi* indicate specific differences.

On most culture media *P. cinnamomi* grew profusely with abundant tough, almost wiry, aerial mycelium, which in old cultures was slightly brownish from the profuse development of vesicles. Cultures of *P. cambivora* remained white, and were less profusely aerial. The Porto Rico and Sumatra strains of *P. cinnamomi* proved indistinguishable. All were pathogenic to wounded potato tubers while *P. cambivora* was not.

The host range was extended by Ashby's identification of the species on Oncidium and the writer's (228) isolation of it from Persea in Porto Rico.

16. *Phytophthora mexicana* Hotson and Hartge Phytopath. 13:520. 1923.

"Mycelium irregularly branched, hyaline, non-septate when young, often septate and empty when old; sometimes short and knobby; conidiophores at first simple and bearing a single apical conidium but eventually becoming long and much branched; conidia terminal but not inhibiting the growth of the conidiophore, varying greatly in size, more or less inversely pear-shaped, 16-33μ by 16-77μ, sometimes measuring twice as long as wide; papillae prominent, usually forming zoosporangia; zoospores ovoid, depressed slightly on one side, germinating immediately by germ tube; chlamydospores intercalary, sparingly produced, almost spherical 28-44μ in diameter, yellowish when old, germinating by germ tube; oospores yellowish at maturity, nearly spherical, 24-37.4μ in diameter; episporium 4.4μ thick; antheridium terminal or

lateral, somewhat spherical or ovoid, surrounding the base of the oogonium as if penetrated by it as in *P. phaseoli* Thaxter.

"Hab. On the fruit of *Lycopersicum esculentum* Mill. from Mexico."

The description by Hotson and Hartge (100) suggests *P. parasitica* from which they distinguish *P. mexicana* by its larger oospores. Leonian (116) found it similar to *P. erythroseptica* physiologically, and Leonian and Geer (119) proposed to combine it with that species. In M/100 potassium nitrate solution they obtained sporangia of *P. mexicana* with mean dimensions of 50.2x32.9μ. They reported the chief difference the papillate character of the sporangia of *P. mexicana* but considered it of slight importance.

The writer observed a few papillate sporangia in potato dextrose and corn meal agar cultures, and also a few chlamydospores on 3 media. Oogonia averaging 30.7μ and oospores averaging 25.4μ were found in old cultures on lima bean and oatmeal agars (Fig. 6). *P. erythroseptica* produced oogonia and oospores averaging 36.3μ and 31.4μ, respectively. The temperature relations of *P. mexicana* resemble those of *P. parasitica* more than *P. erythroseptica*. The writer's culture was very old, probably a subculture of one of the original isolations. It seems desirable to examine a more recent isolation, although the writer has no knowledge of reports of *P. mexicana* other than by its describers. It appears to be referable to *P. parasitica* in spite of the sparsity of chlamydospores and sporangia in culture, but it seems advisable to retain the species until a study of other isolations is possible.

In pathogenicity *P. mexicana* proved more generally virulent than *P. erythroseptica*, again suggesting a closer relationship to *P. parasitica*

17. *Phytophthora richardiae* Buis. Root Rots caused by Phycomycetes. Typ. Hollandia-Drukkerij, Baarn, 51pp. 1927.
Phytophthora cryptogea var. richardiae Ashby Trans. Brit. Mycol. Soc. 14:254. 1929.

"The mycelium is the same as that of other Phycomycetes. Sporangia vary in size. They are produced by Petri's method, or by cultivating plants in water cultures and infecting the roots with the fungus. Zoospores reniform, biciliate, about 10μ in size, produced in varying numbers in one sporangium. Oogonia produced in oatmeal agar and in tissues of infected roots, obovate, growing through antheridium, diameter of distal end about 34-38μ. Oogonial wall yellow. Oospores about 29μ in diameter, wall 2-2.5μ thick and greenish purple in color.

"Antheridia with protuberances, amphigynous, occurring on other hyphae than the oogonia.

"Very virulent parasite of the roots of the Calla lily causing them to decay. May also penetrate into the corms with the same effect."

Miss Buisman (31) considered *P. richardiae* near *P. cryptogea*, *P. cambivora*, and *P. cinnamomi* because of its non-papillate sporangia and their rarity in cultures and the growth of the sporangiophores through the bases of empty sporangia. She distinguished it from *P. cinnamomi* by its failure to produce chlamydospores and from the other species by its larger and differently colored oospores. Ashby (10) regarded *P. richardiae* too similar to *P. cryptogea* to be considered a separate species and proposed that *P. richardiae* be known as *P. cryptogea var. richardiae*.

Salmon and Ware (187) in 1927 reported non-papillate sporangia on diseased roots in water, usually 52x33μ. Ashby (10) reported non-papillate ones in water, with a mean size of 41.7x26.2μ. He also reported oogonia abundant in culture on various agar media. The oogonia were 29-48μ (average 39μ) and the oospores 19-41μ (average 30.7μ). The writer's cultures failed to produce sporangia or oogonia on solid media except in oatmeal agar cultures over-wintered out of doors at Columbia, Mo. In this respect it behaved like *P. cryptogea*. Observations by Ashby (10) and the writer failed to confirm Miss Buisman's (31) report of greenish purple oospores; the writer has not noted that they differ in color from those of other species. Oogonia averaging 28.9μ and oospores averaging 25.4μ were observed; these averages are not very different from those for *P. cryptogea*. (Table 11).

On corn meal agar *P. richardiae* developed best at about 20°C. and failed to grow at 10°C. and 30°C., while *P. cryptogea* grew at 10° and 30°C., and most luxuriantly at 25°C. *P. richardiae* proved non-pathogenic to the following hosts which were attacked by *P. cryptogea*: apple fruits, potato tubers, tomato fruits and seedlings, and eggplant fruits. Unfortunately only one isolation of each species was available for comparison; should the differences between these prove characteristic of other isolations also, the retention of *P. richardiae* as a species may prove advisable.

18. *Phytophthora boehmeriae* Saw. Rept. Dept. Agr. Res. Inst. Formosa 27, 73 pp. 1927.

Mycelium intercellular, 4-8μ in diameter; haustoria short, palmate, 6-6.5x3.5-4μ; sporangia papillate, shortly or elongately ovoid, 27-72x 20-46μ (average for 400 sporangia 49.9x34.5μ), with papillae 9-12x9-14μ; zoospores produced freely; sexual organs produced in diseased leaves and in artificial media (bean agar, potato agar) within one week; oogonia spherical, smooth, colorless to brown, on bean agar 26-41μ (mean 34.9μ), in bean and potato decoctions somewhat smaller; oospores spherical, smooth, colorless, with a wall 2-3μ thick, on bean agar 23-35μ (mean 29.4μ), somewhat smaller in bean and potato decoctions; antheridia

terminal on hyphae other than those bearing oogonia, amphigynous, nearly spherical, 12-16x11-15μ.

Attacks the leaves, but not stems, of *Boehmeria nivea* in Formosa.

The description was compiled from a translation of Sawada's (189) studies sent by S. F. Ashby. Sawada did not mention chlamydospores which the writer obtained fairly abundantly on steamed corn meal and sparsely on other media. They were 16-51μ (average for 400, 41.42μ). Sporangia developed freely in the writer's cultures on most media, averaging 51.77x40.08μ with a range of 28-69x20-51μ. Oogonia and oospores appeared promptly and abundantly as reported by Sawada (189) and proved smaller in size, as follows: oogonia 20.9-31.7μ (ave. 26.5μ); oospores 15.7-27.6μ (ave. 23.3μ). The antheridia were always amphigy nous.

Sawada (189) reported that *P. boehmeriae* behaved, in growth, much like *P. cactorum* at various temperatures. This is confirmed by the writer's studies (Table 24). The species invaded apple fruits rapidly and failed to infect potato tubers. *P. boehmeriae* may be distinguished from *P. parasitica* by its early production of oogonia and its lower optimum temperature; from *P. palmivora* by the early and profuse development of oogonia; from *P. capsici* by the same characteristic and the formation of chlamydospores in culture; from the group including *P. erythroseptica*, *P. cambivora*, *P. cryptogea*, *P. richardiae* and *P. drechsleri* by its papillate sporangia and the ready production of reproductive organs; from the group including *P. infestans*, *P. phaseoli* and *P. thalictri* by its rapid growth on culture media; and from *P. cactorum* and *P. syringae* by its amphigynous antheridia and larger sporangia. The species seems to be a valid one.

19. *Phytophthora heveae* Thomp. Malay. Agr. Journ. 17:53. 1929.

"Mycelium submerged on agar media, and not formed on potato blocks, non-septate when young, 2-7μ in width. Sporangia present on most agar media, and in water culture to which a seed of *Vigna catjang* is added, but absent or few in number on potato agar; somewhat irregular in shape, varying from spherical to narrowly ovate; sporangiophore frequently inserted laterally. Range of sporangia 27-66x20.5-48μ, average of 400=45.49x29.62μ. Mean ratio of length to width=1.55. Oogonia and oospores freely formed on potato dextrose and other agar media and also in water. Oogonia broadly funnel-shaped with amphigynous antheridia. Oospores round, smooth, and thick-walled, not always colored distinctly. Range of 200 oogonia=17-32μ, mean=25.91μ, range of 250 oospores=15-26.8μ, mean=21.46μ. Parasitic in Malaya on bark and fruit of *Hevea brasiliensis* (H. B. K.) Muell. Arg. Para rubber."

This species is known only from the description by Thompson (219), who distinguished it from *P. meadii* by its lack of aerial mycelium, differently shaped oogonia, smaller and more numerous oospores and more elongated sporangia; and from *P. parasitica*, *P. colocasiae*, and *P. palmivora* by the lack of aerial mycelium and the absence of chlamydospores. The writer has not seen *P. heveae*.

20. *Phytophthora drechsleri* n. sp.

Hyphae continuous when young, becoming septate with age, similar to those of other Phytophthoras; vegetative growth luxuriant on steamed corn meal, potato dextrose agar, oatmeal agar, etc.; sporangia rare on the solid media used; in Petri's mineral solution sporangia developing more frequently, non-papillate, ovate, pyriform to obpyriform (Fig. 2) 24-38x15-24μ (average of 50 sporangia 31.4x21μ), germinating by germ tubes or zoospores; sporangiophores slightly smaller in diameter than the hyphae, usually simple with a single terminal sporangium, resuming growth through the base of the evacuated sporangium and producing new sporangia within or beyond the walls of the empty one; true chlamydospores not observed, but swollen irregular vesicles superficially resembling chlamydospores sometimes developing terminally on the hyphae; oogonia broadly clavate to subspherical, hyaline to light amber, smooth, 21.7-53.4μ (average 31.3μ); oospores spherical, smooth, hyaline to lemon-colored, contents granular, 16.7-45.1μ (average 25.6μ); antheridia amphigynous, penetrated by the oogonial stalk, persistent, subspherical to irregular, variable in size.

On corn meal agar (pH 6.2) the optimum temperature for vegetative growth is between 30°C. and 32.5°C. Growth occurs at temperatures between 10°C. and 37.5°C.

Known only from the type isolated by Charles Drechsler from rotting tubers of *Solanum tuberosum* L. from Idaho, U. S. A.

P. drechsleri is a member of the group containing *P. cinnamomi*, *P. erythroseptica*, *P. cambivora*, *P. cryptogea*, and *P. richardiae*, and is believed to be the first of the group isolated on the continent of North America. *P. cinnamomi* was previously obtained by the writer in Porto Rico. Morphologically, *P. drechsleri* is very similar to *P. erythroseptica*, *P. richardiae*, and *P. cryptogea*. In old oatmeal agar cultures kept at room temperatures a few oogonia were found which measured 26.7-53.4μ (Fig. 3), averaging 39.1μ, and oospores 20-45.1μ, averaging 32.1μ. In oatmeal agar cultures overwintered out-of-doors at Columbia, Mo., they were abundant. The oogonia averaged 29.1μ and the oospores 24μ. *P. cinnamomi* differs from *P. drechsleri* in producing chlamydospore-like vesicles promptly and abundantly. *P. cambivora* failed to produce oogonia in oatmeal agar cultures.

Physiologically, *P. drechsleri* may be distinguished from the other species of the group by its high optimum temperature (30-32.5°C.) and its development on corn meal agar at 35°C. The minima, optima and maxima for the closely related species are as follows: *P. cambivora*, 15°C., about 27.5°C., 32.5°C.; *P. cinnamomi*, 10°C., 25-27.5°C., 32.5°C.; *P. cryptogea*, 5°C., about 25°C., 30°C., *P. erythroseptica*, 15°C., 25-27.5°C. 27.5-30°C.; *P. richardiae*, 15°C., 20-25°C., 27.5°C. It has been noted that the temperature requirements of different strains of the same species do not vary widely, and the ready development of *P. drechsleri* at 35°C. and its higher optimum indicate that it is distinct from these morphologically similar species.

P. drechsleri infected inoculated apple fruits, potato tubers, eggplant fruits and seedlings, and papaw and tomato seedlings. *P. cambivora* did not attack potato tubers. *P. cinnamomi*, *P. cambivora*, and *P. erythroseptica* failed to infect any of the seedlings attacked by *P. drechsleri*. *P. richardiae* proved non-pathogenic in all inoculations. *P. cryptogea* was most like *P. drechsleri* in pathogenicity.

Isolations of individual species vary in virulence. Single isolations only of *P. drechsleri*, *P. erythroseptica*, *P. richardiae* and *P. cryptogea* were available for comparison, and the differences in pathogenicity may prove to be of less importance than indicated by the results obtained with these few cultures.

P. drechsleri resembles *P. parasitica*, *P. parasitica var. nicotianae* and *P. capsici* in growing on corn meal agar at 35°C. It is easily distinguished from these by its rare production of sporangia on solid media, the non-papillate character of those produced on solid or liquid media (Fig. 2), and the absence of chlamydospores.

The morphologic and physiologic characters of Drechsler's isolation do not agree with those of any of the species examined; the differences in behavior are so definite that its consideration as a new species seems justified.

Other species.—References to species named but not described are occasionally found. The position of such species cannot be determined.

P. agaves Villada was reported by Gándara (84) on *Agave americana* in Mexico. No description is known.

P. fici Venkata Rao (229) was isolated and provisionally named. It was reported causing a soft rot of the fruits of *Ficus carica* in India. It is possibly *P. palmivora* which causes a similar disease elsewhere.

P. citri Venkata Rao (229) is another provisionally named and undescribed species reported attacking fruits of *Citrus medica* in the Barbadubans.

P. cyperi-rotundati Sawada* was described in 1927 by Sawada (189)

P. lepironiae Sawada was described in 1919 as occurring in Formosa. No translation of the description has been available.

in Japanese. He did not obtain it in culture and the writer has not seen a translation of his description. It must, therefore be excluded from the list of species considered here, although it may be distinct from those previously known.

Blepharospora aurantii Peyr. was mentioned by Dufrenoy (63) in 1925. He regarded it as very similar to Leonian's *P. omnivora parasitica*. The writer has not found a description of *B. aurantii*.

An auxiliary key for the identification of species.

A. No growth on malt extract agar and only meager growth on ordinary agar media after 6 days at 20°C.
   1. Oogonia with amphigynous antheridia produced promptly (within 2 weeks) and abundantly on oatmeal agar at about 20°C. Parasitic on *Phaseolus lunatus*. 3. *P. phaseoli*.
   2. Oogonia produced late and sparsely or absent on oatmeal agar at 20°C.
      a. Parasitic on *Thalictrum spp.* 6. *P. thalictri*.
      b. Parasitic on Solanaceae or Scrophulariaceae. 1. *P. infestans*.

B. Widely spreading growth on malt extract agar and ordinary agar media after 6 days at 20°C.
   1. Oogonia developing promptly (within 2 weeks) and abundantly on oatmeal agar and steamed corn meal. *Antheridia predominatingly paragynous.*
      a. Profuse growth on corn meal agar after 4 days at 26-28°C. 2. *P. cactorum*.
      b. No growth on corn meal agar after 4 days at 26-28°C. 8. *P. syringae*.
   2. Oogonia developing promptly and abundantly, or late and sparsely, or absent on lima bean, potato dextrose, corn meal and oatmeal agars and on steamed corn meal. *Antheridia predominatingly amphigynous.*
      a. Growth on corn meal agar (plate cultures) after 4 days at 35°C.
         (1) Sporangia papillate in agar cultures.
            (a) Chlamydospores produced, at least in old cultures, on oatmeal agar.
               (aa) Non-pathogenic to well-grown stems of *Nicotiana tabacum*. Wide host range. 9. *P. parasitica*.
               (bb) Pathogenic to well-grown stems of *Nicotiana tabacum*. Known, with certainty, only from that host. 10. *P. parasitica var. nicotianae*.
            (b) Chlamydospores absent, even in old cultures, on ordinary agar media. Pathogenic to well-grown stems of *Capsicum annuum* and known only from that host. 14. *P. capsici*.
         (2) Sporangia non-papillate, rare on ordinary agar media, but produced on mycelium transferred to Petri's mineral solution. No true chlamydospores produced. 20. *P. drechsleri*.
      b. No growth on corn meal agar (plate cultures) after 4 days at 35°C.
         (1) Sporangia papillate on ordinary agar media.
            (a) Sporangia and chlamydospores usually produced promptly (within 2 weeks) and abundantly on ordinary media. Oogonia rare, usually absent. Pathogenic to wounded ripe apple fruits. Optimum temperature 27.5-30°C. 7. *P. palmivora*.
            (b) Sporangia produced promptly, but chlamydospores abundantly only in old cultures. Oogonia unknown. Pathogenic to wounded apple fruits. Optimum temperature 25-27.5°C. 5. *P. citrophthora*.

(c) Sporangia and chlamydospores produced promptly. Oogonia produced on oatmeal agar after two weeks. Non-pathogenic to wounded apple fruits. Optimum temperature about 27.5-30°C. 4. *P. colocasiae.*

(d) Sporangia and chlamydospores produced promptly. Oogonia produced *very* promptly (within one week) on ordinary media. Pathogenic to wounded apple fruits. Optimum temperature approximately 25°C. 18. *P. boehmeriae.*

(2) Sporangia non-papillate, rare on ordinary agar media, but developing on mycelium transferred to Petri's mineral solution.

(a) Oospores on oatmeal agar, averaging 30μ or above in diameter. 11. *P. erythroseptica.*

(b) Oospores on oatmeal agar, averaging less than 30μ in diameter.

(aa) Profuse growth on corn meal agar (plate cultures) after 4 days at 30°C. Pathogenic to wounded apple fruits. 13. *P. cryptogea.*

(bb.) No growth on corn meal agar (plate cultures) at 30°C. Non-pathogenic to wounded apple fruits. 17. *P. richardiae.*

(c) Regular or irregular, lobed, branched, or clustered swollen vesicles superficially resembling chlamydospores produced in abundance terminally on the hyphae on agar media. Oogonia rare. Pathogenic to wounded potato tubers. 15. *P. cinnamomi.*

(d) Hyphae on agar media usually sterile. Vesicles occasionally developing, and oogonia rarely. Non-pathogenic to wounded potato tubers. 12. *P. cambivora.*

Synonymous species.—Combination of species which proved identical in the investigations cause the omission from the key of some names which appear frequently in the literature. For easy reference the following synonymy is given; it includes only the modern synonyms, as complete synonymies are listed with the descriptions of the species in previous pages.

2. *P. cactorum* (L. and C.) Schroet. (*P. fagi* Hart); (*P. omnivora* DeBary); (*P. pini* Leon.); (*P. pini var. antirrhini* Sun. and Ram.); (*P. citricola* Saw.); (*P. paeoniae* Coop. and Port.).

5. *P. citrophthora* (Sm. and Sm.) Leon. (*Pythiacystis citrophthora* Sm. and Sm.).

7. *P. palmivora* Butler (*P. faberi* Maubl.); (*P. theobromae* Colem.); (*P. omnivora var. arecae* Colem.); (*P. arecae* (Colem.) Pethyb.); (*P. fici* Hori); (*P. carica* (Hara) Hori); (*P. meadii* McRae).

8. *P. syringae* Kleb. (*P. hibernalis* Carne).

9. *P. parasitica* Dast. (*P. melongenae* Saw.); (*P. allii* Saw.); (*P. terrestris* Sherb.); (*P. parasitica var. rhei* Godf.); (*P. jatrophae* Jen.); (*Blepharospora terrestris* (Sherb.) Peyr).

10. *P. parasitica var. nicotianae* n. var. (*P. nicotianae* Breda de Haan); (*P. tabaci* Saw.).

11. *P. erythroseptica* Pethyb. (*P. erythroseptica var. atropae* Alcock).

12. *P. cambivora* (Petri) Buis. (*Blepharospora cambivora* Petri).

14. *P. capsici* Leon. (*P. hydrophila* Curzi).

17. *P. richardiae* Buis. (*P. cryptogea var. richardiae* Ashby).

Discussion.—*P. thalictri* was not seen by the writer. Leonian (116) found it similar to *P. phaseoli* and *P. infestans* in failing to grow on malt extract agar and his criterion for the separation of the group is used with the addition of a designated temperature, since it is probable that none of this group will grow on any media at high room temperatures (26-28°C.). All are slow growers on media, even under optimum conditions. Fortunately they may be identified without extensive cultural work. *P. phaseoli* and *P. thalictri* are very narrowly parasitic and no other Phytophthora is known on their hosts. *P. infestans* is readily separated from other species occurring on its host by its cultural characters.

Most of the species grow well on all media used. These are divided into groups on the basis of the prevailing type of antheridia, a character which seems constant in culture. The species with paragynous antheridia are *P. cactorum* and *P. syringae*, both of which develop oogonia early and abundantly. *P. cactorum* has more prominently papillate sporangia and produces them more profusely than *P. syringae*, but the species may be distinguished with more certainty by their temperature relations as noted in the key.

All the remaining species produce oogonia with amphigynous antheridia. In some the occurrence of sexual organs in pure culture is rare while others form them regularly. All these species characterized by rapid growth on agar media and the formation of oogonia with amphigynous antheridia or by failure to produce oogonia, fall into two groups; one group growing in plate cultures on corn meal agar at 35°C., the other failing to grow at that temperature. Of all the species studied only *P. parasitica*, *P. parasitica var. nicotianae*, *P. capsici* and *P. drechsleri* grew at 35°C. The first 3 of these produce papillate sporangia in culture. *P. parasitica* and *P. parasitica var. nicotianae* produce chlamydospores more or less abundantly, at least in old cultures on oatmeal agar. *P. parasitica var. nicotianae* may be distinguished from *P. parasitica* only by its ability to infect well-grown tobacco stems and produce the disease commonly called black shank. In nature the variety seems to occur exclusively, perhaps, on tobacco. *P. parasitica* also attacks tobacco, especially in the small seedling stage, and inoculations of older stems are necessary to distinguish it from the variety. *P. capsici*

does not form true chlamydospores in culture. Occasionally swollen vesicles may occur in the hyphae, but they are not likely to be mistaken for chlamydospores. *P. capsici* is known only from pepper (*Capsicum annuum*) and differs from all other species in attacking wounded well-grown stems of that host. *P. parasitica* isolated from pepper fruits proved non-pathogenic to stems. *P. drechsleri* is easily identified by its non-papillate sporangia, rare on agar media, but produced in liquid cultures.

The species which fail to grow on corn meal agar in plate cultures at 35°C. may be divided into two groups based on the morphology of the sporangia. The first group, species with papillate sporangia, contains *P. palmivora*, *P. citrophthora*, *P. colocasiae*, and *P. boehmeriae*. *P. palmivora* usually produces sporangia and chlamydospores early and profusely on most media, but, as previously noted, atypical strains occur which produce them more slowly and in fewer numbers. Such strains may be identified by their failure to grow at 35°C., their pathogenicity to apple fruits and their optimum temperature of 27.5° to 30°C. *P. citrophthora* resembles *P. palmivora*, especially the atypical strains of the latter which develop chlamydospores slowly in culture. *P. citrophthora* produces them abundantly only in old cultures. It may be distinguished from *P. palmivora* by its lower temperature range, the optimum being between 25° and 27.5°C. *P. colocasiae* produces oogonia on oatmeal agar, and is non-pathogenic to apple fruits. *P. boehmeriae* produces oogonia earlier and more abundantly in culture than *P. colocasiae* and is pathogenic to apple fruits. It also differs from *P. colocasiae* in its temperature relations.

The species which spread rapidly on ordinary media, fail to grow at 35°C., and produce non-papillate sporangia are *P. erythroseptica*, *P. cryptogea*, *P. richardiae*, *P. cinnamomi*, and *P. cambivora*. The first 3 species produce oogonia regularly on oatmeal agar if kept at about 20°C. The writer found it necessary to grow them at room temperature in the tropics and oogonia were produced very scantily. In Missouri they developed more abundantly. *P. erythroseptica* may be distinguished by the large size of the oospores. *P. cryptogea* and *P. richardiae* produce oospores of similar size, but *P. cryptogea* grows on corn meal agar in plate cultures at 30°C. while *P. richardiae* does not. *P. cryptogea* is pathogenic to apple fruits, but *P. richardiae* is not. *P. cinnamomi* very rarely produces oogonia in culture. It may be distinguished from all other species by the very profuse development of vesicles on the hyphae in culture on agar media. *P. cambivora* is usually sterile on solid media; vesicles are occasionally found; it may also be distinguished from *P. cinnamomi* by its non-pathogenicity to wounded potato tubers, which are attacked by *P. cinnamomi*.

It will be noted that little use of the average sizes of the reproductive organs has been made in selecting criteria for the differentiation of the species. As repeatedly observed by the writer and others, the sporangia vary widely in size and shape among different isolations of the same species, and the chlamydospores vary greatly in average diameter. As previously stated, the size of these organs is of some value as an aid in identification, but cannot be used as a lone criterion. The size of the oospores is used to separate *P. erythroseptica* from related species, this species producing oospores larger than those of any other developing them regularly in culture; when further knowledge of the oospores of *P. cinnamomi* and *P. cambivora* is obtained it is possible that they may be found to equal those of *P. erythroseptica* in size. Two species, *P. mexicana* and *P. heveae* are omitted from the key for reasons previously stated.

The type of growth on culture media, whether appressed, aerial, radiate, regular, etc., has not been used. As observed by Leonian (116) and confirmed by these investigations, growth characters vary with particular isolations, substrata, temperature, etc.

The characters used as criteria, the antheridial type, the character of the sporangia (papillate or non-papillate), the temperature relations, etc. are those which have been found very characteristic for the species. The occurrence of an occasional apparently or actually amphigynous antheridium in a species producing numerous paragynous ones should not be confusing; nor should the occasional presence of a non-papillate sporangium among numerous papillate ones in *P. parasitica*, for example, cause that character to have less value for differentiating species.

The temperature relations are used as criteria as the result of comparative studies which indicate that the behavior of different isolations of the same species does not vary widely and that each species exhibits rather definite responses to temperature. When the differences in response are marked the use of the character as an aid in identification is considered justified.

The use of pathogenic characters in connection with others will, in some cases, simplify identification, which is, of course, the principal aim of the investigation. The characters used as criteria seem best adapted to the use of those interested in determining the identity of isolations, and the key may prove of assistance if used in connection with the characters discussed in previous pages.

III. Summary.

A collection of 150 isolations of Phytophthoras, representing most of the known species and the more important hosts in various regions, was used in the investigations reported.

The isolations were grown on various ordinary culture media and compared as to growth characters and reproduction.

Morphological studies on the character and size of the sporangia, chlamydospores and vesicles are reported, as well as on the character of the antheridia and the size of oogonia and oospores.

Results of inoculations of cotton bolls, potato tubers, fruits of cacao, tomato, eggplant and apple, stems of Ricinus, papaw, tomato, eggplant, cacao, grapefruit, tobacco, and pepper, detached Bryophyllum leaves and other plants are reported. Different isolations of the same species vary in pathogenicity and there is evidence of the existence of biological strains within some species, but they do not exhibit the narrow specialization and high degree of host selectivity observed within some other fungous species. Phytophthora species may, in some cases, be identified by their ability to infect certain hosts; *P. capsici* and *P. parasitica var. nicotianae* were the only Phytophthoras which infected well-grown stems of pepper and tobacco, respectively.

The ability of Phytophthoras in oatmeal agar cultures to survive exposure to winter temperatures in Missouri seems to be determined by an inherent character of the protoplasm of particular species or strains. It is, apparently, not generally correlated with the development of sexual spores or a particular type of asexual reproductive organ. *P. cambivora*, producing mycelium only, survived regularly.

Neither does the ability of species to survive as long as one year in culture in the laboratory appear to be correlated with the production of particular types of spores.

The Phytophthoras were grown on corn meal agar in plate cultures at various temperatures between 5° and 37.5°C. Different species vary widely in their temperature relations and especially in their abilities to develop at the higher temperatures used. Different isolations of the same species behave very similarly and indicate that the response to temperature is a specific character. The temperature relations are regarded as of taxonomic value.

Isolations of *P. palmivora* which did not develop oogonia and oospores in pure culture did produce them when certain isolations were grown in mixed cultures, thus confirming reports by others. A brief survey of the recorded evidence regarding heterothallism, hybridism and stimulation of sexual reproduction caused by the presence of another mycelium is submitted and discussed.

The taxonomic position of the genus and the species is considered in detail. The most valuable characters for their differentiation in culture are ability to grow on certain media, type of antheridium, character of the sporangia, temperature relations, and, in a few species, the development of certain types of reproductive organs, size of oospores and pathogenicity.

The following species are maintained as identifiable by the criteria suggested: *P. infestans*, *P. cactorum*, *P. phaseoli*, *P. colocasiae*, *P. citrophthora*, *P. thalictri*, *P. palmivora*, *P. syringae*, *P. parasitica*, *P. erythroseptica*, *P. cambivora*, *P. cryptogea*, *P. capsici*, *P. cinnamomi*, *P. mexicana* (doubtful), *P. richardiae*, and *P. boehmeriae*. Another species *P. heveae*, known only by the description, is included. *P. cyperi-rotundati* has never been isolated, nor has a translation of the Japanese description been available.

P. parasitica var. nicotianae n. var. is suggested as a name for the strains which are morphologically very like *P. parasitica*, and cause black shank of tobacco.

P. drechsleri n. sp. is described; the species was isolated from rotting potato tubers by Drechsler. It resembles morphologically, the group with non-papillate sporangia but is very different in temperature relations.

P. fagi, *P. omnivora*, *P. pini*, *P. pini var. antirrhini*, *P. citricola* and *P. paeoniae* are considered indistinguishable from *P. cactorum* and regarded as identical with the last.

P. arecae, *P. fici*. *P. carica*, *P. faberi* and *P. meadii* appear very like *P. palmivora*, a common tropical species containing many strains which exhibit considerable variation in growth characters, sporulation and pathogenicity. All are combined as *P. palmivora*.

P. hibernalis is combined with *P. syringae*, the prior species.

P. parasitica, a species widely distributed in the temperate and tropic zones, includes *P. melongenae*, *P. allii*, *P. terrestris*, *P. parasitica var. rhei*, *P. jatrophae* and *Blepharospora terrestris*.

P. tabaci is combined with *P. parasitica var. nicotianae* on the basis of characters mentioned by its describer.

P. erythroseptica var. atropae is included in *P. erythroseptica* pending further evidence that it shows differences in physiology or morphology justifying its separation.

P. hydrophila is combined with the earlier species, *P. capsici*, to which it exhibits very marked similarity in morphologic and pathogenic characters.

A key is given for assistance in identifying the species.

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